Developing a framework for the classification of strategic and critical minerals in South Africa

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December 2022

DECLARATION

I Dikgwatlhe IP declare that the thesis has been composed by me and that the work has not been submitted for any other degree or professional qualification at any university. I can confirm that the work submitted is my own work, except where work has formed part of jointly authored publication and has been included.

Signature: ______________________

ABSTRACT

Minerals should be sufficient to sustain security of the nation as well as growth of the economy and employment. Countries without minerals may source minerals from mineral-rich countries. South Africa is endowed with mineral resources and has a comparative advantage in minerals such as manganese, chromium, vanadium and platinum amongst others. Mineral wealth can contribute towards resolving the challenges of a high rate of unemployment, poverty and inequality.

Most of the minerals in South Africa are exported as raw materials and once produced, final products are sold back to the country and imported as finished products. Trade-offs between exports as raw ore or beneficiated minerals which have a higher value should be considered for contribution in this country towards industrialisation and employment. Identified and selected critical and strategic minerals can promote economic growth and industrialisation. An assessment methodology utilising three categories namely, economic importance, risk and impact was used to develop a framework to classify minerals as strategic and critical in South Africa. Thirty-eight minerals were identified, eighteen potential strategic and critical minerals selected and most contributing seven strategic are selected according to economic importance, risk and impact factors. The framework contributes to policy-making, economic growth, and security of supply. It also promotes development of minerals and optimises value from the minerals and their economic use and enhances industrialisation and employment.

In this research a survey was also conducted on the perceptions of local people at or close to mines on the positive and negative socio-economic impacts of mining in their communities. The first outcome indicated that mining communities and employees are aware of the mineral wealth of the country and have lamented on the level of poverty and inequality of employment experienced in their areas where mining activities are taking place.

The study further revealed misunderstandings and unfulfilled expectations concerning the responsibilities of the mining companies and the accountability of the government towards the community. Limited resources and desperation for opportunities by employees and communities could lead to a disaster in the mining industry if these perceptions are not addressed.

Keywords: Strategic and critical minerals, socio-economic, Framework, communities, mining.

ACKNOWLEDGEMENTS

I would like to thank my supervisors and family for the support and guidance towards completion of this work. Above all, I would like to thank the Almighty God who provided me with strength and wisdom to persevere throughout the years of the study.

LIST OF PUBLICATIONS

The following research journal and conference papers were extracted from the research study:

- Dikgwatlhe, P., 2018. Coal as a strategic resource in South Africa. Society of Mining Professors 6th Regional Conference 2018, Birchwood Hotel and Conference Centre, Johannesburg, 12 – 13 March 2018, The Southern African Institute of Mining and Metallurgy.
- Dikgwatlhe, P., Mulenga, F., 2022. Perceptions of local communities regarding the impacts of mining on employment and economic activities in South Africa. Resources Policy, vol. 80, #103138.
- Dikgwatlhe, P., Mulenga, F., 2022. Platinum as a strategic mineral in South Africa. Resources Policy, *in preparation.*

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Abbreviation	Acronym/Symbol
BIC	Bushveld Igneous Complex
BGS	British Geological Survey
CGS	Council for Geoscience
DFFE	Department of Forestry, Fisheries and the Environment
DMRE	Department of Mineral Resources and Energy
DoD	Department of Defence
DoE	Department of Energy
DSTI	Department of Science, Technology and Innovation
DTI	Department of Trade and Industry
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EIA	Energy Information Agency
EMPR	Environmental Management Programme
EU	European Union
GDP	Gross Domestic Product
GVA	Gross Value Add
HHI	Herfindahl-Hirschman Index
IRP	Integrated Resource Plan
MCSA	Mineral Council South Africa
MEG	Mineral Exploration Group
MPRDA	Mineral and Petroleum Resources Development Act
NDP	National Development Plan
NerSA	National Energy Regulator of South Africa
NIR	Net Import Reliance
NRC	National Research Council
NSTC	National Science and Technology Council
NT	National Treasury
PGE's	Platinum Group Elements
PGMs	Platinum Group Metals
RBCT	Richards Bay Coal Terminal
REE	Rare Earth Elements
SAMCODES	South African Mineral reporting Codes
SAMREC	South African code for the reporting of mineral exploration results, mineral resources and reserves
SME	Subject Matter Expert
SLP	Social and Labour Plan
StatsSA	Statistics South Africa
UNEP	The United Nations Environment Programme
USGS	United States Geological Society
WGI	World Governance Index

CHAPTER 1: INTRODUCTION

1.1. Background

South Africa has a large global contribution of platinum group metals, gold, diamonds, manganese, coal, iron ore and chrome. The country has most of the platinum (87.7%) and manganese (80%) resources in the world. South Africa's Department of Mineral Resources and Energy (DMRE) also reported the top four highest income contribution from PGMs (R346,525,549,000), coal (R150,098,372,000), iron ore (120,781,852,000) and gold (102,209,471,000) of South Africa's total commodity sales (DMRE, 2021). The country is therefore well-endowed in mineral resources and exports most of its raw materials (DMRE, 2021). Table 1.1 shows a summary of commodity sales in South Africa as of 2021.

Table 1.1: Summary of sales of key commodities.

Group	**Commodity**	**Local sales**	**Total sales**	**Total Exports**	**Exports**
		R'000	R'000	R'000	% of total sales
GOLD, PGMs, DIAMONDS AND SILVER	Gold	9,155,869	102,209,471	93,053,603	91.0
	PGMs	25,253,878	346,525,549	321,271,671	92.7
	Diamonds	7,928,797	21,139,007	13,210,210	62.5
	Silver	119,554	463,617	344,063	74.2
	Sub-total	**42,458,097**	**470,337,644**	**427,879,547**	**91.0**
BASE MINERALS	Chrome	11,230,705	21,974,540	10,743,835	48.9
	Copper	601,743	2,745,652	2,143,909	78.1
	Iron Ore	5,101,679	120,781,852	115,680,173	95.8
	Lead concentrate	3,664	846,283	842,619	99.6
	Manganese	2,757,122	37,098,932	34,341,810	92.6
	Nickel	1,872,249	9,162,970	7,290,721	79.6
	Zinc	0	7,084,935	7,084,935	100
	Coal	86,381,343	150,098,372	63,717,030	42.5
	Other non-metallic	3,428,913	7,406,106	3,977,193	53.7
	Miscellaneous	13,715,710	22,096,430	8,380,720	37.9
	Sub-total	**125,093,127**	**379,296,073**	**254,202,946**	
	Grand total	**167,551,224**	**849,633,717**	**682,082,493**	

Source: DMRE (2021)

From Table 1.1, it can be deduced that more than 90% of the total export sales are accounted for by the following minerals: platinum group metals (PGMs), silver, iron ore, lead concentrate, manganese, nickel and zinc (DMRE, 2021).

It is evident that mineral resources greatly contribute to the South African economy. The mineral resources should therefore be utilised and exported optimally for the benefit of the country and its citizens. Resources exported to the United States (US), for example, include fluorspar, manganese, gemstones, titanium, garnet, platinum, chromium, silicon, zirconium, palladium and vermiculite (US Geological Society, 2016). In a sense, South Africa is still a resource-based economy. This is also the case with most African countries. However, environmental concerns and mineral policy continue to affect investments in the mining industry on the continent.

To illustrate this coal, oil and natural gas are arguably the most important sources of energy world-wide. Oil and natural gas are produced in selected countries and sold at a high purchase price to non-producing nations or countries without oil and natural gas. Many African countries thus resort to coal as an affordable alternative (Energy Information Agency, 2009). It is therefore understandable that the exploitation of the abundant bituminous coal estimated at 66.7 billion tons in South Africa (DMRE, 2015) has been reported to contribute the highest income both locally and for foreign exchange in the past six years. Figure 1.1 indicates how South Africa depends on coal as its main source of energy and revenue.

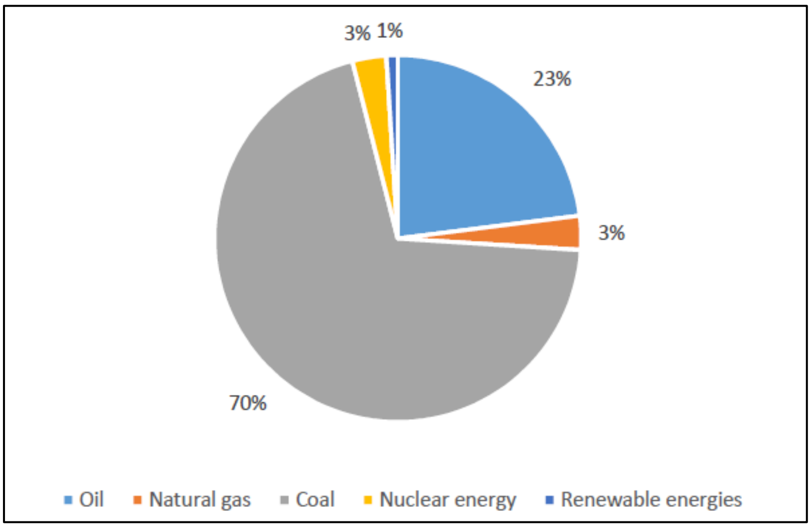


Figure 1.1: Electricity distribution in South Africa.

Based on Figure 1.1, it may be argued that coal will not be replaced easily in South Africa. This is especially true considering that Southern Africa supplies approximately 27% of its fuel for electricity generation in the world (Energy Information Agency, 2018). In South Africa, approximately 92% of electricity and 34% of liquid fuel are generated from coal extracted by conventional mining. According to Eskom, coal contributes 80.1% of the electricity to the country while other sources are nuclear (4.6%), wind (4.4%), solar PV (2.2%) and hydro (1.4%) (Eskom, 2023). If coal was to stop being mined, the negative impact on direct employment, associated indirect services, and electricity supply may be huge.

Mining is a long-term investment and security of tenure is important for investors and shareholders. The tenure entails five principal stages: exploration, production, processing, marketing of one or more of the products, and rehabilitation of the disturbed land and polluted water. Production refers to mining-related activities such as ownership, estimating reserves and resources, selecting equipment, undertaking wise capital investment, ensuring appropriate labour practice, and identifying adequate infrastructure and logistics including terminals for export (Anderson and Anderson, 1998).

Mining communities and employees struggle to make sense of approximately 52.8% average level of poverty and inequality experienced in their areas vis-a-vis the mineral wealth extracted as a result of mining activities taking place (Flomenhoft, 2019; StatsSA, 2022). Legislation and friendly policies instituted as part of corporate social responsibility and social labour plan could be used to address this problem. This is because of the general expectation for improved quality of life based on employment and sharing of the wealth coming from the minerals. On the other hand, environmental organisations are more concerned about the impact of mining activities rather than the socio-economic impacts that coal and mining in general bring. Such organisations call for closure of coal mines on account of contaminated water and poor land rehabilitation practices at the end of the life of the mine, amongst others.

The anticipated employment that coal mining brings, it should be noted that South Africa suffers from the threefold problem of poverty (55.5%), unemployment (35.3%) and higher inequality (StatsSA, 2021). This was evident in different proposals made by communities, employees and their unions to consider nationalisation of mines, operating state-owned mines, and beneficiation of raw materials in South Africa before exporting finished products to other countries (Limpitlaw, 2011). The rise of nationalism, nationalisation of resources, expropriation, increased taxation, and implementation of constraints on foreign ownership is not a new phenomenon in the third world (Kessel, 1990). However, many foreign-owned mining companies are concerned about nationalisation of mines, expropriation of land and constraints on ownership proposed in South Africa. Concerns are also raised about the recent government-proposed idea to tax the export of raw mineral commodities in order to retain the use of such materials for local manufacturing (South African Government, 2020). Be that as it may, mines are already experiencing disruptions of operations and unrest by employees and local communities for better quality of life and increased employment.

The main reason for these disruptions is the perceived gap between the expected benefits for the local community and what the mines are actually doing as reported in their corporate social responsibility. In addition, there is lack of understanding by the communities and employees of what mining companies are expected to do and the responsibilities of the municipality in that community.

This can result in strikes as was seen in the Madibeng area in the North-West. In this instance, members of the various communities in the area blocked the roads to the mining operations demanding employment and community development. They accused the mines of employing people outside their communities (Africa News Agency, 2018). Employees then embarked on several underground sit-in protest actions for better wages. The disputes went on for months and resulted in the loss of revenue and production (Mining weekly, 2018). South Africa experienced another disaster in the platinum industry known as Marikana Massacre on 16th August 2012 where 34 mine workers lost their lives (Alexander et al., 2012). This also was a quest for a better living wage.

The need to mine South Africa's mineral resources in order to provide funds for its economy and jobs for neighbouring communities can lead to misunderstandings of employment and economic contribution of the mining industry. Elbra (2013) illustrated this by arguing that South Africa is suffering from the effects of the resource curse. This refers to the fact that the proceeds from commodities pass out of a country and are not used to benefit those within (Sachs and Warner, 2001).

Limited resources and desperation can also lead to volatility in the mining industry and the country at large. In September 2019, some South African citizens embarked on a protest action. They targeted both national and foreign nationals' businesses accusing them of crime-related activities and of taking employment opportunities from nationals.

Acts of violence and attacks on foreign nationals living in South Africa were first experienced during the period of recession in May 2008 (Dodson, 2010). These attacks were labelled by some analysts as xenophobic while the government refuted them as pure criminality. In any case, hunger and a struggle for limited resources are the cause for Africa being at war with itself.

Some citizens also pressurised the government to nationalise mines and review the mining charter as well as the Mineral and Petroleum Resources Development Act (MPRDA, 2002). The idea was to ensure increased benefits for the community and partners. The ruling party embarked on a feasibility study for nationalisation, but the decision was ultimately not to follow this route. This was due to a lack of funding and limited capacity for the government to embark on such a major initiative, amongst others.

In terms of electricity supply, a stable power grid is required for the abundant mineral wealth to change the lives of citizens and strategically position South Africa. Indeed, the country experienced a shortage of coal supply at the state-owned power utility company which resulted in power outages. The prolonged energy crisis brought about by under-investment in the electricity sector led to high power prices, shortage of power supply capacity, load-shedding, and blackouts (Pollet et al., 2015). Concerned citizens started to question the security of the supply of mineral resources by the country. In attempting to address the energy crisis, the government decided to employ independent power producers and commit to renewable energy. This led some to believe that the decision may cause job losses in the energy sector. Protest actions ensued as illustrated in Figures 1.2 and 1.3 due to fear of changes in coal supply and perceived impact of independent power producers (Hyman and Mabena, 2015).

Figure 1.2: Trucks used to blockade the national roads into the capital city Pretoria.

Figure 1.3: Trucks blockading the national roads during a protest action.

Another challenge is that high quality coal was exported to international countries while low quality coal was supplied to the state-owned power utility. This action led to the belief that low quality coal is affecting power stations by incurring high maintenance costs to the boilers and other related equipment.

A suggestion regarding a moratorium on coal exports to deal with the quality and shortage of supply at the power stations was raised. While a pronouncement on the matter was yet to be made, entities such as steel making plants, mining companies and related stakeholders in the value chain were suffering due to a shortage of electricity supply. Some closed, while others were placed on care and maintenance. Most mineral producers started downsizing their labour complement and production output. This situation jeopardised all plans for national economic growth.

Previous discussions (DMRE, 2015) were held with regard to ensuring security of supply of mineral resources such as coal to ESKOM, the state-owned power utility company. The promotion of beneficiation to enhance industrialisation in South Africa was also deliberated upon. These engagements resulted in debates about declaring some minerals as strategic. The process was not completed in 2015 when these matters were last formally discussed. Instead, some minerals were selected as important resources (i.e., minerals that can be used in the value chain) in the beneficiation strategy of South Africa. The aim of the beneficiation strategy is to promote the development of "important" minerals and optimise their value. Their economic use in different stages of the value chain is therefore, expected to enhance industrialisation and employment for the benefit of South Africans (DMRE, 2011). To put this into perspective, the mining industry contributed 6.8% of the Gross Domestic Product (GDP) as well as direct employment of 464,667 employees including indirect benefits for approximately 4.5 million of their dependants to the country in 2017 (StatsSA, 2017). As such, more than 6.5 million people will lose their jobs if mining was to stop. This figure includes those directly employed on the mines and power stations, the South African Coal, Oil, and Gas Corporation (Sasol), a state-owned company, and metallurgical industries. The impact may be extended to those indirectly dependent on the mining sector like service providers, road and rail transporters, engineering manufacturers, road builders, and employees' families and beneficiaries.

All these stakeholders would suffer if there was to be no salary coming from employment in the mining industry. This would add to the already high rate of unemployment, poverty and inequality recorded in the country (StatsSA, 2022). In order to address this situation, it is vital to encourage the mining industry to ensure adequate employment in the most responsible manner. This, however, needs to be balanced by two factors: mine mechanisation and export/import balance. In the first instance, plans need to be made to bring the employees and the community into the mining table discussion. Due consideration should then be made for the future mechanisation of ancillary operations such as mine rehabilitation. In terms of the second factor, the country's mineral resources should be wisely balanced between the export needs and the use of the same commodities locally. The development of a framework that can be used to classify mineral commodities in South Africa may assist. The best use of commodities would ensue for the greater benefit of all.

There are minerals that are strategic and critical to the country (Glöser et al., 2015). The government should consider them with a dedicated designation with a view to meet the future economic, social and industrial needs of the country. For this to happen, mineral supply in the country should be utilised to sustain the security of the nation, the growth of its economy and the employment of people. Strategic minerals generally support military, industrial or commercial activities. They find use in renewable energy technologies, military and medical equipment, electronics, agricultural products and household items. A drafted policy on these minerals should therefore, form part of national security and ensure the safety of the country, its citizens and collaborators (Kessel, 1990).

The reliability and availability of the supply of strategic and critical minerals in a country are important (Helbig et al., 2016). As such, the analysis of the future of minerals in South Africa is useful for its strategic economic global positioning.

Nations such as the US and the European Union (EU) already possess classification frameworks for strategic and critical minerals aligned with their specific needs (USGS, 2016). In this light, a framework that can be used to classify strategic and critical minerals in South Africa was developed in the present study. With the proposed framework, a list of strategic and critical minerals can be compiled for the country. The security of supply and policy recommendations were also considered in the development of the framework in line with South Africa's National Development Plan (NDP, 2012). Finally, a literature review was conducted, and a survey administered to support the development. From the literature review, existing frameworks from developed countries were considered. The South African context and its own dynamics were finally infused so as to refine the proposed classification framework.

1.2. Problem statement

South Africa is endowed with mineral resources but has no framework for the classification of strategic and critical minerals. Countries have developed frameworks for sourcing and utilisation of strategic and critical minerals to benefit its citizens. They have identified and compiled a list of these minerals. South Africa needs a list of designated minerals reviewed and updated periodically. This framework is to ensure the optimal utilisation of mineral resources for the benefit of the country and its citizens. The framework is also set to be a tool for regularly exploring and evaluating the future of strategic and critical resources as well as their impacts on the South African economy.

The mining sector is critical to the socio-economic development of South Africa. However, the country has adopted private ownership of mineral rights whereby prospecting and mining licenses are awarded to private owners who exploit minerals and hold discussions with communities (MPDRA, 2002).

The problem is that most raw materials are exported raw and sold back to the country at exorbitant prices. The country imports 26% goods and services and export 30% as a percentage of GDP and raw material import product share is 10% while the export is 30% (StatsSA, 2021).

Trade-offs, therefore, should be considered in terms of beneficiation and criticality of minerals. These sums up the research problem explored in this study.

This study is designed to assess the hypothesis that certain minerals are strategic and critically important and, if utilised optimally, have significant impact on the economy and socio-economic conditions of the country.

1.3. Research objectives and questions

Ensuring that the citizens of South Africa benefit from the mineral wealth of the country is an ongoing interest. The study of strategic and critical minerals is one avenue that may inform the decisions and policies towards this imperative, which can also contribute towards resolving the challenges of unemployment, poverty, and inequality.

1.3.1. Main Objective

The main objective of this research is therefore to develop a framework for the classification of strategic and critical minerals in South Africa.

1.3.2. Sub-Objectives

1. In addition, the research will focus on the socio-economic impacts of mining in the community to develop an analytical framework. The perceptions of local people living in the vicinity of mines about the socio-economic impact of mining activities in their communities are investigated.

2. The study further attempts to establish and evaluate the benefits, constraints and impacts of declaring minerals as strategic and critical to the South African economy.

1.3.3. Research question

To this end, the work aims to answer the following research questions: Will South Africa benefit from mineral resources declared strategic and critical and enhance its economic and strategic position?

1.3.4. Research Sub-questions

1. What are critical and strategic minerals?
2. How can South Africa benefit from strategic and critical minerals?
3. What are the socio-economic impacts of mining in the local community?

In trying to answer this central research question, an in-depth review of the existing body of knowledge was done to identify a set of criteria and implement a process for the classification of minerals as strategic and critical. The benefit of the classification framework was then considered with the view of enhancing the economic and strategic position of South Africa.

Finally, surveys were administered to local people in order to gauge their perceptions about the socio-economic impacts of mining activities in their community, amongst others.

1.4. Significance of the study

The South African mining sector is renowned globally for its production of minerals and its contribution to the world. Neglecting this sector can lead to inconsistent policy and a decline in mineral production, mineral processing capabilities, and economic value-add.

It is therefore critical to promote industrialisation in the country in an effort to deal with poverty, unemployment and inequality. This should enable the country to utilise mineral resources optimally for the benefit of its citizens. However, despite the fact that a national beneficiation strategy exists, no listing and framework for strategic and critical minerals are available in South Africa.

Other countries such as US and EU (McCullough and Nassar, 2017; National Research Council, 2007) developed various frameworks to ensure best utilisation of resources, security of supply of minerals, and improved economy. It is therefore important to explore strategic and critical minerals' potential to influence and affect policy options in South Africa. As such, the outcomes from this study are expected to contribute to and promote the achievement of the objectives of the national development plan of South Africa.

1.5. Scope of the study

Mining companies operate in different areas and provinces of South Africa where various commodities are exploited. Associated mining activities may take place in and around communities such as towns, townships as well as rural and farming areas. Informal settlements also develop within the communities around the mining operations. This research was conducted in the local communities within the mining towns, townships and informal settlements of the North-West, Limpopo, Mpumalanga, and Gauteng.

The study focused on the sites where the minerals that have been mined have the potential to be listed as strategic and critical for the country. These minerals mostly contribute to the economy of the country with employment in local communities. Minerals of interest include gold, platinum group minerals, diamonds, chrome, coal, iron ore, manganese, copper, vanadium, lithium and rare earth elements.

1.6. South African context

In this research study, the aim of the development of a framework for strategic and critical minerals in South Africa is to assist, support and complement the beneficiation strategy outlined in the National Development Plan objectives (The National Planning Commission, 2012). In some respects, what constitutes a critical mineral depends on who is asking the question (USGS, 2018). It is therefore mostly dependent on the needs and requirements of the market, producers, consumers, investors, shareholders, communities, employees, employers and the government.

The three main categories for the classification of strategic minerals are economic importance of the mineral, risks associated with supply or demand and impact in the nation's security and economy. Frameworks are developed from different perspectives pertinent to the national needs. Other countries (e.g., the USA and countries in the EU such as France, Finland, Netherlands, Sweden, and United Kingdom) developed their own framework from a different perspective considering their needs, and one of the most important factors they have focused on is supply risk from selected countries due to their reliance on net import (EU, 2014).

This study is set out to develop a framework to classify strategic and critical minerals in the South African context. The study assesses the applicability and relevance of the assessment methods (discussed in Section 2.4) developed for strategic and critical minerals in other jurisdictions. South Africa is a mineral-rich country (mining industry contributed 8.7% to GDP) (MCSA, 2021); therefore, the focus is from the perspective of its specific needs that hinge on demand risk and reliance on the net export of commodities.

South Africa is the world leading producer of chromium (44%), manganese (37%), palladium (42%) and platinum (72%) (USGS, 2022), One of the major factors in the South African mining industry is the impact and contribution of the electricity supply. This is because of the effects of load-shedding on many mining operations, processing plants and smelters that are peculiar to South Africa. Finally, technology, expertise, capital and infrastructure are considered in the study, as these are key to a successful mining industry.

1.7. Organisation of the thesis

The thesis is organised in eight chapters. The first chapter covers the introduction to the research, the context, the need for the research, and the scope of the work done. Chapter two provides a review of the literature relevant to the intended research. The different methods that have been used to classify and list minerals and raw materials as strategic and critical in several countries are being reviewed. A deductive approach is applied to these methods to select relevant and applicable strategies for South Africa. Previous studies and findings are also considered in terms of the socio-economic impacts of mining in different countries. In other words, the perceptions of the local communities surrounding nearby mining operations are analysed for selected jurisdictions. This enabled the researcher to lay the foundation for the work that needs to be done in the South African context.

Chapter three outlines the research methodologies adopted for the study. The approach to the research design, methods and instruments for collecting data towards developing the framework is also presented.

Chapter four is the characterisation of the surveyed sample and profile of participants where the results of the data collected are presented.

In addition, a screening methodology is discussed to identify potential strategic and critical minerals including the implementation process and associated roles and responsibilities for selecting potential minerals.

In chapter five, the proposed analytical framework for assessing the socio-economic impacts of mining according to the survey is discussed. The focus is on the quantitative and qualitative analysis of the third impact factor in the three categories of the strategic and critical minerals: economic importance, risk and impact.

Chapter six discusses the methodology and assessment of the proposed framework for the classification of strategic and critical minerals. The focus is mainly on the quantitative and qualitative analysis of the economic importance and risk factors in the three categories of the strategic and critical minerals. Relevant South African factors are considered in the classification. Selected assessment methods of strategic and critical minerals are considered to develop a framework to classify and compile a list of strategic and critical minerals.

Chapter seven presents the complete framework according to the categories of the strategic and critical minerals and the benefits. Further discussion is on the compiled list of the strategic and critical minerals as well as the results on the perceptions of local communities on the socio-economic impacts of mining.

Chapter eight concludes the study, highlighting the major findings of the study of the perceptions from local communities and the developed framework of the strategic and critical minerals. The findings are aligned to the hypothesis and central research question. Finally, recommendations from the study are made and future studies in relation to the aspects of the framework are suggested.

References are compiled to acknowledge the contribution of previous researchers on the topic and related studies.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Earth resources can be found from three sources: air, water, and land. These sources contribute economically and socially to the nations of the world by improving the quality of life (Perrings et al., 2003). Original supply of material in life are either mined or grown. This makes the mining and agricultural sectors to be the primary sources for the original supply in life. The economic growth of most nations therefore depends on the availability, quality, utilisation and adequate supply of these resources. Mineral resources and energy are primarily required at the beginning of most life cycles and are therefore, critical because of their significant use in society (National Research Council, 2007).

This research focuses on the land resource, that is, mineral resources. Air- and water-related aspects to mining and community are also discussed. Different minerals are deposited spatially in different countries of the world. Fifteen minerals, namely, aluminium, chromium, cobalt, copper, gallium, indium, lithium, nickel, PGM's, REE's, silicon, tellurium, zinc, graphite and manganese were identified as critical for energy transition by different agencies (i.e., IEA-2021, IRENA-2022, USGS-2022, EC-2020, Canada-2020) according to their needs across different countries (Srivastava, 2023). These minerals contribute to the economy of the country and the social well-being of the society. Some minerals are more important to the nation than others depending on their specific contribution. These minerals are classified as strategic and critical to the nation's security, economic growth and employment (Kessel, 1990; Haglund, 1984).

2.2. Strategic and critical minerals

The concept of strategic minerals dates back to the 1930's (Haglund, 1984). It is a contested concept and is subjective. It depends on who is posing the question and whether the minerals are strategic for important use. The term strategic minerals started during the interwar in the United States. Shortages and difficulties of supply of specific materials during wartimes affected the US. The first list of materials was drafted by C.K. Leith in 1917. The US War Department drafted a list of materials known in the 1920's as a Harbord List of materials which did not only include minerals. It is during this time when the label strategic material was introduced. The category that was used to analyse materials which were critical then followed in the 1930's (Haglund, 1984).

Strategic terminology was associated with defence where materials were supplied wholly or in large quantities from foreign countries. Strict conservation and control measures were necessary to mitigate potential supply restrictions and shortages. The term critical was also important for defence, but potential supply restrictions and shortages were not much of a concern compared to strategic materials (Haglund, 1984).

There is a difference between strategic and critical minerals. Strategic minerals are necessary for national security, industrialisation, economic growth, and employment in the country. Strategic minerals are vital for application and different uses, but vulnerable to potential supply disruptions. Few or unsatisfactory substitutes exist in most cases, and their absence will result in negative economic or social consequences (Haglund, 1984). "Strategic" means planned, tactical and calculated (Haglund, 1984). The potential disruptions in supply may be due to depletion, difficulty in extracting in an economically or in an environmentally acceptable way, and a reliance on supplies from a limited number of mines, amongst others (National Research Council, 2007).

Critical minerals or resources are mostly important within the specific period and purpose. Therefore, a mineral that is critical for the manufacturer (e.g., steelmaking, motor industry, etc) may not necessarily be critical for the country. “Critical” means vital, important, essential, crucial or significant (Haglund, 1984). Environmental and technological aspects should be considered in determining the criticality of the mineral. Minerals or resources that are used for military purposes and security of the nation are strategic. The minerals that are in short of supply pose a threat or that can harm the economy are critical. Therefore, a critical mineral may or may not be strategic while a strategic mineral will always be critical (National Research Council, 2007).

Classification of strategic minerals is subject to change for certain minerals depending on the availability of their substitutes and new improvements in technology that may render them useless for the country or its importance. Strategic minerals can be explained as minerals that are needed to sustain modernised industry, and their supply is subject to any time restriction depending on their important uses and vulnerability (Gustafsson et al., 1990).

2.3. Important factors for other countries

Some factors such as import reliance and production relating to the development and classification of critical and strategic minerals are considered important by US and EU countries (EU, 2014). A perspective from these countries for these minerals is mostly a supply approach, that is, net import reliance, where the critical and strategic minerals supply needs to be secured from identified countries.

A draft list of critical minerals was compiled using the early warning screening methodology which was developed by US National Science and Technology Council (NSTC) in 2016.

The United States used the two-stage method to apply a screening methodology of minerals to assess their criticality (McCullough and Nassar, 2017; NSTC, 2016). The first stage is an indicator stage with the following three indicators: supply risk (R), production growth (G) and market dynamics (M).

The disruptions because of shortage of production and geopolitical restrictions of mineral supply from foreign countries will result in a threat to the nation’s economy and security. Risks identified were price fluctuations because of shortage, supply disruptions because of geopolitical shifts in government over time, rapid increases in demand and other supply chain factors. Once the risks are noted, the country will establish risk management strategies and diversify mineral supplies, develop substitutes for materials and technologies using that specific mineral, increase recycling, and ensure efficient use of critical minerals.

The two-stage assessment methodology refers to the first stage which is an early warning screening tool that identifies potentially critical minerals, and the second stage which consists of in-depth supply chain analyses of selected minerals identified by the screening tool. Early warning screening tool uses indicators such as supply risk, production growth and market dynamics to assess the potential criticality of a mineral (NSTC, 2016).

The tool is updated annually using mineral production and price data. In the analysis conducted, a subset of 20 minerals based on the criticality potential value greater than 0.3 were identified for further study. These minerals are yttrium (Y), rare earths (La-Lu, gallium (Ga), ferromolybdenum (FeMo), mercury (HG), tungsten (W), ruthenium (Ru), antimony (Sb), silicomanganese (SiMn), graphite (C), germanium (Ge), ferronickel (FeNi), monazite, strontium (Sr), iridium (Ir), tantalum (Ta), rhodium (Rd), bismuth (Bi), niobium (Nb), and phosphate (P). A strategy was developed to ensure secure and reliable supply of critical minerals (NSTC, 2016).

This strategy includes developing a list of critical minerals; approaches to reduce reliance on critical minerals, actions to support increased support of domestic supplies of critical minerals; identifying new sources of critical minerals; increasing activity from exploration, mining, concentration, separation, alloying, recycling and reprocessing; easy electronic access of data to explorers and producers; and refining the processes of issuing permits and access to the mining area (USGS, 2016).

2.3.1. Supply risk

The principal metric used was the Herfindahl-Hirschman Index (HHI), which identifies the highly concentrated markets when a company may control a market share above an established threshold of 2,500 on a scale that ranges from 0 to 10,000. It was concluded that the production of high-demand minerals for the US is concentrated in few foreign countries which created a high risk of price increases and supply disruptions. Supply risk captures the risk associated with the concentration of production in countries with low governance (McCullough et al., 2017).

2.3.2. Production growth

Growth in the screening methodology evaluates the growth of world production to highlight a commodity’s growing importance. A few important aspects of production concentration or growth include trends (changes in global demand), comparative advantages, government policies to secure domestic supplies, and geological distributions and occurrences. A high concentration of production is an important component of criticality. HHI is a metric market concentration measure used to quantify production concentration, is the sum of the squares of each producing nation’s global production share of a commodity in a given year (USGS, 2016).

2.3.3. Market dynamics

The market for strategic and critical minerals is driven by demand and supply. A new use of a mineral in the important technology and contribution to the economy may increase the potential demand for a specific mineral. This is where price volatility is assessed to understand the stability of the commodity's market (USGS, 2016).

2.3.4. Net import reliance (NIR)

According to Nassar et al. (2002), the net import reliance (NIR) is not the same as import vulnerability. Import vulnerability is defined as a material or mineral with high NIR that is sourced from a country or countries with high governance risk. NIR, on the other hand, exists because domestic production is either lacking or insufficient to satisfy domestic demand by consumers. NIR is calculated as the amount of imported material minus exports, and changes in government and industry stocks and is expressed as a percentage of domestic consumption (Nassar et al., 2002).

Promotion and support of local production as well as improvement on efficient use of minerals and materials are important to address some domestic demand. Rare metals are produced as by-products during the extraction of other metals and ores, so if these other metals and ores (e.g., molybdenum) are not mined such valuable rare metals will be unavailable because they are uneconomical to mine on their own.

2.3.5. Market strategies developed by other countries

Different countries developed strategies for their strategic and critical minerals according to the needs of the country. Several minerals were selected and policies with goals were drafted for the minerals of interest (see Table 2.1).

Table 2.1: Strategic goals of different countries with policies and minerals of interest

Country	Goal	Business Policy	R&D Policy	Materials of Interest
China	Maintain a stable supply of raw materials for domestic use through industry consolidation, mitigating overproduction and reducing illegal trade	• Establish taxes and quotas on rare earth element (REE) exports • Prohibit foreigncompanies in REE mining • Consolidation industry • Create unified pricing mechanism • Establish production quotas	• Explore new rare earth separation techniques and new rare earth functional materials • Establish three additional labs and twoinstitutions focused on REE mining and applications	Sb,Sn,W,Fe,Hg. AI,Zn,V,Mo and rare earth elements
European Union	Limit the impact of potential supply shortages on the European economy	• Build a mineraltrade policy for open internationalmarkets • Gather information • Streamline land permti ting •Increase recycling regulations	•Increased material efficiency in applications • Identification of material substitutes • Improve end-of-life product collection and recycling processes	Sb,Be,Co,Ga, Ge,In,Mg. Nb, REEs,Ta,W, Fluorspar and Graphite
Japan	Secure a stable supply of raw materials for Japanese industries	• Fund international mineral exploration • Guarantee loans for high-risk mineral projects • Stockpile materials • Gatheringinformation	• Explore substitution research funded through Ministry of Economy, Trade and Industry and the Ministry of Education, Culture,Sports, Science and Technology • Complete exploration, excavation,refining, and safety research funded through the Japan Oil Gas and Metals National Corporation	Ni,Mn,Co,W, Mo and V
Australia	Maintain investment in the miningindustry while fairly taxing the depletion of national resources	• Establish a low tax on the value of extracted resources • Create a high tax on mine profits • Allow tax rebates for mineral exploration • Ensure fast turnaround for land permit applications	• Promote sustainable development practices in mining and processing • Map resources	Ta,Nb,V,Li and rare earth elements
Canada	Promote sustainable development and use of mineral and metal resources, protect the environment and public health and ensure an attractive investment climate	• Require accountability in environmental performance and mineral stewardship • Use a life cycle-based approach to mineral management and use • Promote a recycling industry and incorporate recycling as part of product design	• Provide comprehensive geosciences information infrastructure • Promote technological innovation in mining processes • Develop value-added mineral and metal products	AI, Ag, Au, Fe, Ni, Cu, Pb and Mo

Source: EU (2014)

A French strategic-metals plan was developed in 2010 where critical minerals and materials were identified (i.e., cobalt, gallium, germanium, indium, lithium, niobium, rare earths elements, rhenium, selenium and tantalum) which included suggestions to the government to make plans in securing future supply of critical materials. They used the EU criteria to classify critical minerals and materials.

Finland developed a minerals strategy in 2010 to exploit their known and potential mineral resources to 2050, which will ensure that their domestic mineral sector is dynamic and competitive. Germany developed a raw materials strategy in 2010 to ensure a sustainable and stable supply of critical materials for the economy (EU, 2014). Their main policy aim is to improve competitiveness and resources as well as to promote research and development.

The Dutch raw-materials policy developed in 2011 focused on securing availability and improving sustainability of critical materials, restricting national demand, and improving efficiency and sustainability of raw materials to the economy (EU, 2014). A resource security action plan developed in 2012 by the United Kingdom was aimed at developing a strategy for natural resources in order to address resource risks, concerns and a framework for business and review on resource strategies and research (EU, 2014). The Sweden mineral strategy mostly focused on leading mining in the region to create growth by sustainably using natural resources of the country. The strategy has taken into consideration the environment, nature and cultural values (EU, 2014).

2.4. Assessment methods for strategic and critical minerals

Different methods are used to assess strategic and critical minerals that have been used and applied in different countries. The countries that are mostly evaluating and assessing these minerals are the US (US mineral commodity summaries) (USGS, 2022), Britain, and other countries in the EU (e.g., France, Germany, and Finland) and UN (EU, 2010).

Assessment methods include the National Research Council (NRC) method, which uses the matrix to assess the criticality of a mineral (National Research Council, 2007), this is presented in Section 2.4.1.

Anderson's geopolitical risk assessment model used to assess the geopolitical risks of the country (Anderson, 1993), this is discussed in

Section 2.4.2; and the European Union (EU) method used to assess and evaluate critical raw materials (Oakdene Hollins and Fraunhofer, 2013; Buchert et al., 2009), this is covered in Section 2.4.3.

The United States Geological Society (USGS) method is used to assess critical elements and minerals based on the magnitude of US import dependence of minerals from outside countries (USGS, 2016). It provides the necessary information for understanding the national, international and global distribution; supply and demand for energy; and mineral resources. The assessment of scientific data and inventories of produced and discovered resources is provided, which includes the assessment of undiscovered resources. The definition of a critical mineral is a mineral that is identified as non-fuel mineral or is essential to the economic and national security of the United States, sourced from a supply chain that is vulnerable to disruption and that serves an essential function in the manufacturing of a product. The absence of this mineral will result in serious consequences to the economy or national security (USGS, 2018). A list of critical minerals is compiled using the early warning screening methodology.

The British Geological Survey (BGS) method is used to assess risk factors of supply (British Geological Survey, 2015). The methodology defines the relative risk of supplying and ranking the minerals. The ranking system is based on seven criteria, of which each is given a score of one, two or three. The criteria applied include production concentration, reserve distribution, recycling rate, substitutability, governance (top producing nation), and governance (top reserve-hosting nation and companion metal fraction). A score of one indicates a low contribution from a particular criterion to supply risk, while a score of three indicates a high risk. The risk list of minerals is compiled and provided from this assessment.

The US Department of Defence (DoD) method is a top-down economic method using the risk assessment and mitigation framework for strategic materials and bottom-up methodology which is used to assess potential shortfall of supply (DoD, 2015).

The United Nations Environment Program (UNEP) method is focused on critical metals for their sustainable technological use in the future including their potential for recycling, where metals under investigation are classified into demand growth, supply risk and recycling restrictions (Buchert et al., 2009). Demand growth can be divided into rapid and moderate growth; supply risks according to regional concentration of mining, or physical, temporary, structural or technical scarcity; and recycling restrictions mostly according to dissipating applications, physical and chemical limitations, lack of suitable technologies, infrastructure and pricing incentive. Metals will be screened and the one that indicates most of criteria for supply risk will be considered as having a serious supply risk (Buchert et al, 2009).

The Federal Institute of Geosciences and Raw materials (BGR), the Fraunhofer institute of systems and innovation research (ISI) and Rhine-Westphalia Institute of Economic research (RWI) of Germany method use the criticality matrix (BGR/ISI/RWI, 2007; Glöser et al., 2015). The US Department of Energy (DOE) also uses the criticality matrix method for strategic and critical minerals (DoE, 2011).

Other countries, namely, China, Japan, Canada and Australia developed strategies and policies for their selected strategic minerals, as discussed in Section 2.3.5.

2.4.1. NRC Method (Criticality Matrix Method)

A criticality matrix methodology has been developed to assist in assessing a mineral's degree of criticality.

A mineral is critical when it is essential to the economic and national security, vulnerable to supply disruption, and essential in the manufacturing of the product without which the consequences are dire.

Disruption is anticipated to be due to natural disasters, labour strife, trade disputes, resource nationalisation, conflict and other factors (USGS, 2017).

The matrix indicates that a mineral is critical if it is both important in use (shown on y-axis of the matrix) and if there can be potential supply restrictions (shown on x-axis of the matrix) (see Figure 2.1).

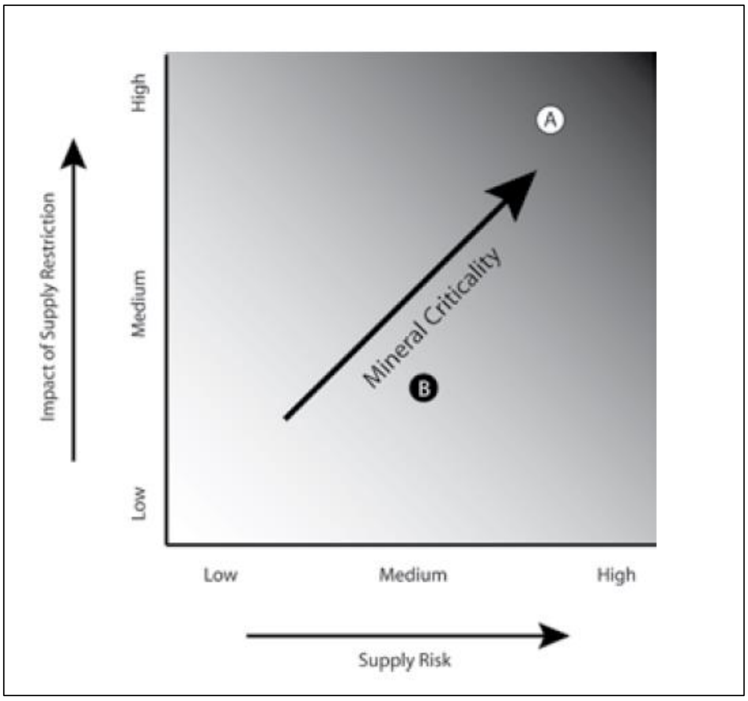


Figure 2.1: Criticality matrix used to assess minerals in the US.

According to NRC (2007), the criticality matrix was applied to 11 minerals to determine whether they are critical to the United States. In Figure 2.2, minerals such as copper, gallium, indium, lithium, manganese, niobium, platinum group metals, rare earth elements, tantalum, titanium and vanadium are used to demonstrate the Criticality Matrix Methodology. The circles for each mineral are represented in a score of 1 to 4 according to its criticality.

Platinum group metals, rare earth elements, indium, manganese and niobium are the most critical minerals (upper right corner in Figure 2.2). Platinum group metals and rare earth elements are useful to the construction and functioning of automobile catalytic converters including the absence of substitutes in their application. The criterion used is based on the importance of use and availability.

Importance of use is mostly linked to the economy. The demand of the mineral from different sectors of the economy is assessed to determine utilisation. The chemical and physical properties of minerals are important, including the difficulty in finding the mineral, expense, or time to find a suitable substitute for a given mineral.

Availability of minerals is determined by the following factors: geology (existence of mineral resource), technical (extracting and processing potential), environmental and social (acceptable production environmentally and socially), political (government policies and availability), and economical (viability to producers and capability and willingness from buyers).

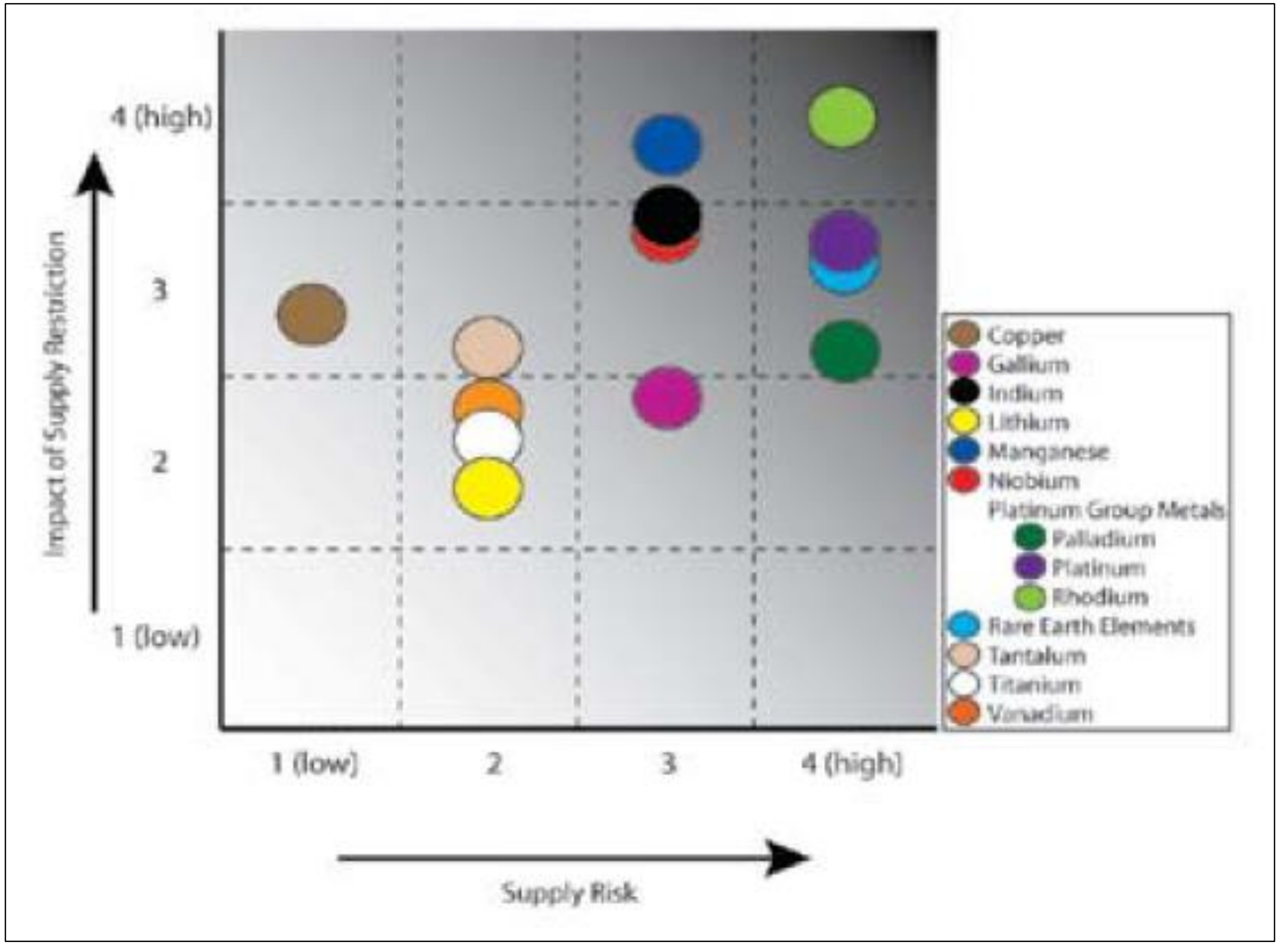


Figure 2.2: The application of criticality matrix to 11 minerals.

2.4.2. Geopolitical Risk Assessment method

This methodology provides a framework to make assessments and determines the data, information and research that are needed to address issues of disruptions on supply and potential restrictions.

The location of the mineralised orebody is important. Anderson's geopolitical risk assessment model for strategic minerals and elements (see Figure 2.3) can be used to assess the strategic importance of minerals by analysing variables according to this formula (Anderson, 1993):

$$RF = (S + LE + SP) + 2 \times (MS + R + WP) \qquad \text{(eq. 2.1)}$$

where S – substitution, LE – Life expectancy, SP – scale of production, MS – number of major sources, R – reliability of main sources, WP – Warsaw Pact's share of global production, RF – is risk factor.

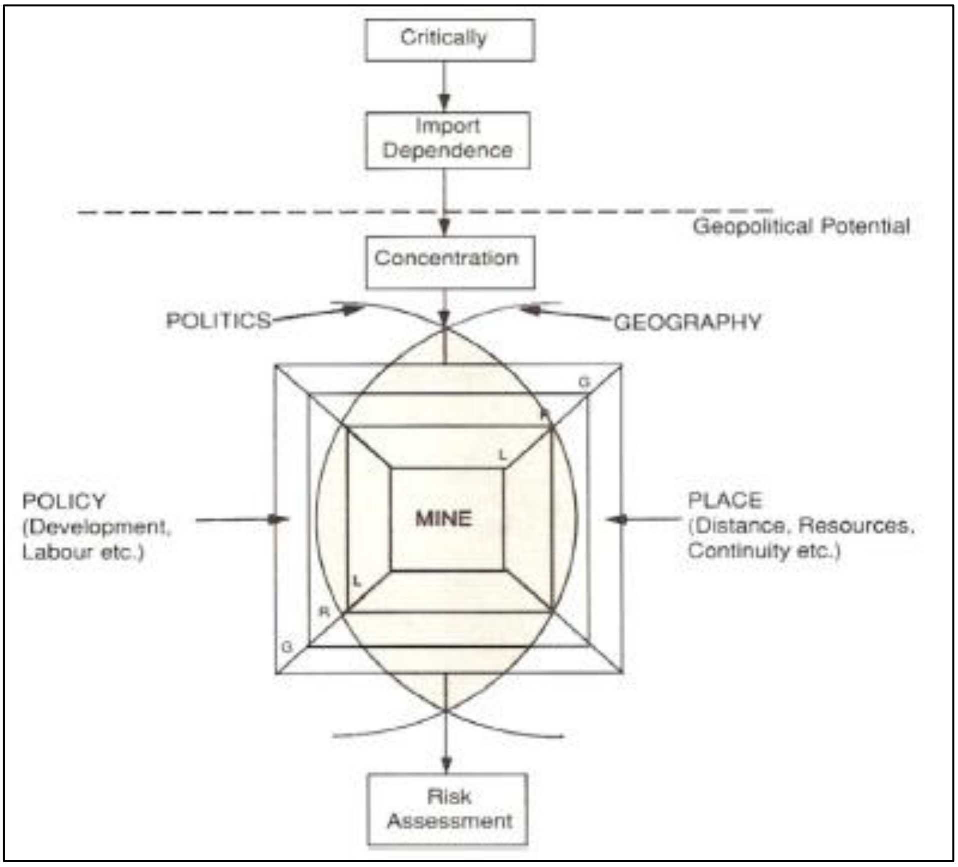


Figure 2.3: Geopolitical risk assessment model.

The selected minerals in the geopolitical risk assessment method are weighted according to the risk factor, for example, geopolitical factors affect the supply of the mineral. In this risk factor, location is important for the minerals and will be classified as strategic based on the geographical location. The seven variables (i.e. substitution, life expectancy, scale of production, multiplier of two on location features variables, number of major sources, reliability of sources and Warsaw Pact's share of global production) are used for estimating the risk factor which is related to geographical aspects. Bulk commodities such as chromium, manganese, platinum, cobalt and tungsten are considered to have the highest risk factor in the model (Anderson and Anderson, 1998).

2.4.3. EU Method

The European Union decided to assess a number of raw materials with a plan to establish a list of raw materials that can be regarded as critical. A methodology was designed to define and assess critical raw materials, which includes three important factors, namely, economic importance, supply risk and the risk of environmental challenges that affect access or supply of that material. Concerns were raised about the relevance of the environmental performance as it does not reflect the reality in the mining sector of certain countries (EU, 2014).

The main two components are economic importance and supply risk. Economic importance is assessed according to the proportion of material associated with industrial mega-sectors, which is then combined with the mega-sectors' gross value adds (GVA) to the EU's gross domestic product. The total is used to define overall economic importance of the material (EU, 2014).

Supply risk is mostly assessed on the concentrated primary supply from countries with poor governance as measured by the world governance index (WGI). Several factors associated with supply risk are substitutability, end-of-life recycling rates, and high concentration of producing countries with poor governance. The material is therefore, defined as critical under this methodology (EU, 2014) if it exceeds both the threshold (3 – 5) for economic importance and the supply risk (see Figure 2.4).

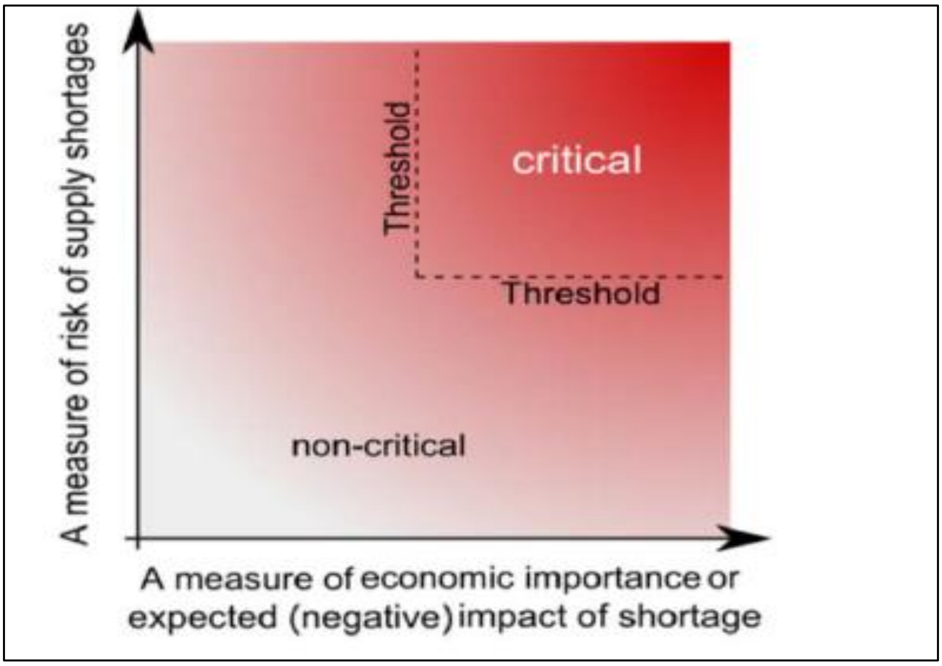


Figure 2.4: Criticality of material relative ranking on two dimensions.

The method was used by an ad hoc committee of the European Union to assess and evaluate critical raw materials. In the first study, 41 raw materials were evaluated, where it showed that 14 materials were critical due to economic importance and supply risk (Oakdene Hollins and Fraunhofer, 2013; Buchert et al., 2009). The method was further used to evaluate 54 minerals and elements for the critical raw materials as shown in Table 2.2. Newly added materials in the list are highlighted in blue and the rare earth elements group was split into three smaller groups (i.e., light, heavy and scandium). The results of criticality analysis showed that 21 of the minerals and elements were critical, as shown in Figure 2.5 (EU, 2014; Hollins, 2013). Table 2.3 shows a list of the critical materials after the analysis.

Table 2.2: List of potential materials

Aluminium	Antimony	Barytes	Bauxite	Bentonite	Beryllium
Borates	Coking Coal	Chromium	Clays (and kaolin)	Cobalt	Copper
Diatomite	Feldspar	Fluorspar	Gallium	Germanium	Gold
Gypsum	Hafnium	Indium	Iron ore	Limestone (high grade)	Lithium
Magnesite	Magnesium	Manganese	Molybdenum	Natural Graphite	Natural Rubber
Nickel	Niobium	Perlite	Phosphate Rock	Platinum Group Metals	Potash
Pulpwood	Rare Earth Elements – Heavy *	Rare Earth Elements – Light *	Rhenium	Sawn Softwood	Scandium*
Selenium	Silica Sand	Silicon Metal	Silver	Talc	Tantalum
Tellurium	Tin	Titanium	Tungsten	Vanadium	Zinc

Source: Oakdene Hollins et al. (2013

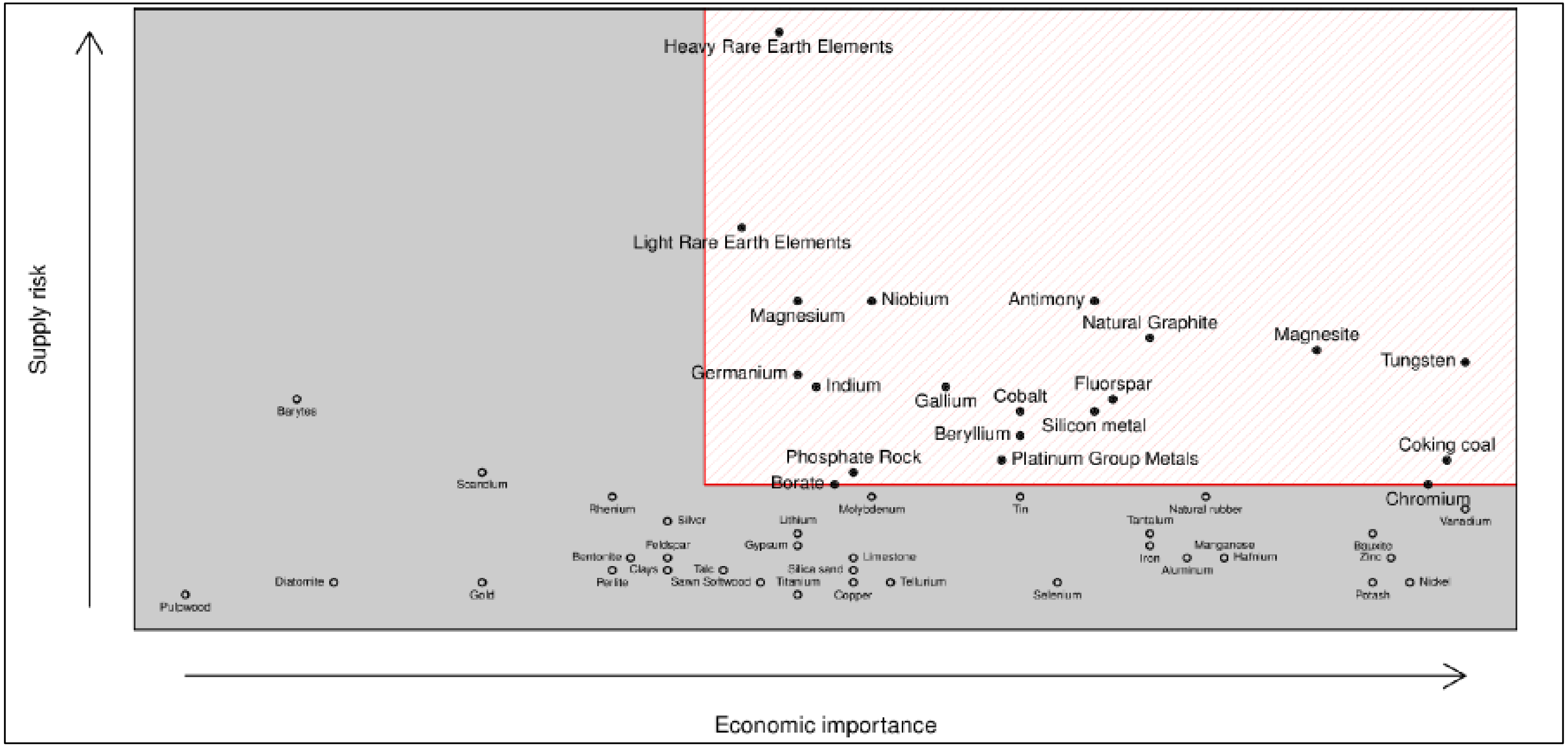


Figure 2.5: Mineral assessment method in EU.

Table 2.3: List of classified critical materials

Antimony	**Beryllium**	**Borates**	**Chromium**	**Cobalt**	**Coking coal**	**Fluorspar**
Gallium	**Germanium**	**Indium**	**Magnesite**	**Magnesiu m**	**Natural Graphite**	**Niobium**
PGMs	**Phosphate Rock**	**REEs (Heavy)**	**REEs (Light)**	**Silicon Metal**	**Tungsten**	

Factors that affect the mineral's importance of use include fundamental specific uses, chemical and physical properties and suitable substitutes. Minerals should be available to be exploited.

Factors that affect availability of minerals are geological, technical, environmental and social, political and economic (NRC, 2007).

The matrix explains that a mineral is critical if it is both important in use and is subject to potential supply restrictions or disruptions. The methodology provides a framework to different stakeholders interested in minerals to make assessments about the criticality of minerals. This will also assist to determine the required data, information and research needed to mitigate disruptions, and restrictions and shortages of supply for current or future use (National Research Council, 2007).

Classification of strategic minerals may change for certain minerals according to the availability of substitutes, and technological changes which may render particular uses obsolete. Strategic minerals are generally those minerals that are essential for the continuance of modern industry and can come from supply sources which can be restricted at any time, depending mostly on essential uses and vulnerable supplies (Gustafsson et al., 1990).

Changes due to availability, technological changes and modernisation of the industry may lead to the development of a new breed of strategic materials. Examples of such challenges are gas emissions, mobile phones and climate change. The fast and rapid pace of technological changes creates a new breed of strategic materials.

Traditional metallic minerals are affected by new technology. These minerals will not be eliminated completely but their usage and demand are expected to decline. The role of less developed countries as suppliers diminishes in favour of countries that are newly industrialised and which reshape the concept of foreign import reliance. The concept of strategic materials may have to include patented processes and technologies. Other materials such as rhenium, gallium and REE will emerge as strategic (Kessel, 1990).

Energy resources can be strategic and critical as they continue to contribute to the economy, security and employment of the nation. The major sources of energy are coal, natural gas and natural oil. The end-product of the sources of energy depends on how they will be utilised. Direct utilisation is mostly for metallurgical purposes and power or fuel. The indirect utilisation from liquid, gas, and minerals will result in the end-product mostly for power or fuel, metallurgical, optical, chemical products, and trace elements (EIA, 2007).

A comparison of the different international criteria and approaches used for strategic and critical minerals in Table 2.4 shows that there are different factors applied by different organisations. There are several factors, namely, supply (i.e., geological and economic availability and recycling), demand (i.e., future demand and substitution), geopolitical (i.e., policy, regulations, risk and supply concentration), and other factors (i.e., environmental issues and economic importance) which affect strategic and critical minerals (Speirs, 2013). The factors with the green dots are applied in the criteria and those in red are not applied in the approach.

Table 2.4: Comparison of list of factors in the criticality assessment of minerals

	CRITERIA AND APPROACH										
	Supply factors			**Demand factors**		**Geo-political factors**			**Other Factors**		
Organisation/ Department	Geological availability	Economic availability	Recycling	Future demand projections	substitutability	Policy & Regulation	Geopolitical risk	Supply concentration	Cost reduction using technology & Innovation	Environmental issues	Economic importance
NRC	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🔴	🟢	🟢
Oakdene Hollins	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
EU	🟢	🟢	🟢	🔴	🟢	🔴	🟢	🟢	🔴	🟢	🟢
DOE (2011)	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴
BGS	🟢	🔴	🔴	🔴	🔴	🔴	🟢	🟢	🔴	🔴	🔴
UNEP	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🟢	🔴	🔴	🔴

Source: NRC (2007); Oakdene Hollins et al. (2013); EU (2014); DOE (2011); BGS (2015); USGS (2016)

2.5. Factors affecting strategic and critical minerals in South Africa

The South African mining industry is affected by different factors such as electricity (power), supply, demand, availability, utilisation, geopolitical risks, income, employment, community, expertise and technology, investment, policy, labour, environment and infrastructure. These factors are important in the assessment of strategic and critical minerals and are used to develop a framework for the classification in the South African context.

The imported material in the country mostly includes finished products such as machinery and equipment, mineral fuels, chemical goods, petroleum products, scientific instruments, food and materials, plastic and plastic articles, vehicles, pharmaceutical products, optical, technical, medical equipment, organic and inorganic chemicals, and other items.

2.5.1. Electricity

Energy is vital for the economy of any country. It has serious impacts in many sectors of the economy. The affected sectors of the economy are the residential, mining, manufacturing, commercial and agriculture sectors. Mining is an intensive electricity-usage industry and will close operations if there is lack of electricity supply (Limpitlaw, 2021). As a result, many people may lose jobs due to unreliable and unavailable power supply because of mine closure. Electricity is assigned a relative weighting of 30% in the assessment methodology in relation to other parameters due to its associated risks and impact to strategic and critical minerals in the country.

Primary energy is generated from fossil fuels, nuclear fuels and renewables. Power generation is important in South Africa, especially considering the effects of load shedding experienced by many mining operations, smelters, plants and other related industries. Security of supply of energy is important to ensure reliable electricity supply (Limpitlaw, 2021).

High electricity prices will affect the mining industry due to high operational costs. Marginal or loss-making mines will close their operations. Therefore, increasing electricity prices alone to ensure revenue for the power utility is not the only solution to the utility and power problems in the country. South Africa is pursuing a diversified energy mix to reduce reliance on coal and explore the alternative energy. Coal, nuclear, natural gas, renewable energy, hydro and energy storage are considered in the energy mix according to the integrated resource plan (IRP). Some coal power stations and Koeberg will reach end of life and new power stations, gas to power technologies, Inga project, renewable technologies will play a significant role in the energy mix (IRP, 2019).

The country can benefit more from beneficiation, renewables and optimised economic contribution. The process of beneficiation requires electricity which is a challenge considering the price hikes announced the National Energy Regulator of South Africa (NerSA). NerSA approved electricity hikes of 9.41%, 8.1% and 5.2% for three years (NerSA, 2019).

Smelting firms such as ferroalloys smelters were closed due to high electricity costs which resulted in mining operations exporting raw minerals from the country. The gold sector will be severely affected by electricity price increases, as these mines use a lot of electricity as a result of the depth of the mines that require more ventilation and cooling underground.

2.5.2. Supply

Exploration activities can provide new ground and resources for the mining operations. New mines will ensure availability of minerals which will directly affect the supply. Shortages in production will adversely impact supply in the form of lack of supply, risk of supply, and shortfall of supply to domestic and international markets. The parameter of supply is assigned a relative weighting of twenty percent according to the risk and impact of effects on the strategic and critical minerals in the framework.

South Africa is not mostly affected by import reliance compared to other developed and developing countries.

2.5.3. Demand

Mineral demand is driven by the importance of use, consumption and market forces (NRC, 2008). It is mostly affected by availability of substitutes, technological changes, modernisation, foreign export reliance/dependence, and international exports (NRC, 2008). The drive and demand for renewable energy will create opportunities for REE and other minerals such as lithium, vanadium, carbon, copper, nickel, manganese and cobalt (Limpitlaw, 2021). South Africa is mostly exporting the minerals (Table 1.1) (DMRE, 2021) and this parameter is assigned a relative weighting of thirty percent in the assessment methodology for strategic and critical minerals.

2.5.4. Availability

The minerals should be available and economical to be mined. Some minerals that may not be available to establish mineral value chains can be sourced externally as strategic minerals. For example, lithium might be strategic for battery manufacturing. Lithium consumption for batteries has increased because of rechargeable batteries used in the industry (USGS, 2022). But batteries do not only contain lithium, so some critical raw materials (e.g., nickel, cobalt, graphite and manganese) required for battery manufacturing might not be locally available. Several factors affect and influence the availability of minerals, such as geology, percentage world supply, technical specifications, environment, politics (i.e., mineral regulation and promotion) and economics (NRC, 2007). Availability is assigned 20% in the assessment methodology considering the impact, abundance and production of strategic and critical minerals.

2.5.5. Utilisation

Mineral resources should be utilised to benefit society and grow the economy. Utilisation of minerals is driven by importance of use (i.e., direct and indirect usage) and market requirements. Lithium and vanadium are used in the new energy economy especially batteries. They are used in different environments and scales, lithium batteries are more mobile, more variable in efficiency and safety while vanadium are effective and big (PWC, 2023). New technology in the market may increase demand for utilisation of minerals. Beneficiation of minerals will grow the economy and create employment through skills development and industrialisation (DMRE, 2011). Utilisation parameter in the assessment methodology of strategic and critical minerals is assigned a relative weighting of thirty percent considering the contribution and importance of use of the minerals in South Africa.

2.5.6. Geopolitical risks

The geographical location and political environment pose a risk to production and mining of the minerals. Factors such as substitution, life expectancy, scale of production, number of major sources, reliability of main sources, Warsaw Pact's share of global production, sanctions, tariffs, trade policy, corruption, and reforms may result in major risks to the minerals (EU, 2014; Anderson et al., 1993). Geopolitical risk is assigned a relative weighting of ten percent.

2.5.7. Income

The mining industry continues to contribute to the livelihood of the country and its citizens. The contribution to income, whether high or low, is dependent on the type of commodity/mineral. The sales made in the mining industry results in the contribution to the economy (MCSA, 2021) (see Table 2.5). The income parameter is assigned a relative weighting of 10%.

The real GDP increased by 4.9% in 2021, whereas mining production increased by 11.8% and contributed 70.5% to the country (StatsSA, 2021). It is believed that the decrease in production was mainly from iron ore, gold and coal. The GDP declined by 1.3% in the fourth quarter of 2022, whereas mining production declined by 3.2% due to high disruptions in electricity supply, constrains in rail transportation and constraints in harbour capacity which contributed to 0.3% contraction to the country (StatsSA, 2022).

Table 2.5: Sales and expenditure in the mining industry in 2021

Sales	2021
	R' Billions
Sales	849633.7
Total sales	**849,633.7**

Expenditure items	2021	%
	R' millions	
Purchases	451,907	45.18
Employment costs	162,840	16.28
Interest paid	25,645	2.56
Royalties paid	17,014	1.70
Rental on land and buildings	26,426	2.64
Rental on plant and machinery	5,051	0.50
Depreciation	48,966	4.90
Losses on assets	42,502	4.25
Taxation	78,093	7.81
Buildings, improvements and construction works	12,727	1.27
Expenditure on plant, machinery, furniture, fittings and other equipment	66,389	6.64
Capital expenditure	3,228	0.32
Other expenditure	59,509	5.95
Total expenditure of mining	**1,000,297**	**100**

Source: MCSA (2021)

2.5.8. Employment

Different mining operations use different mining methods, as determined by the mineralisation and depositional environment. The number of employees is controlled by the type of activity/mineral and modernisation methods utilised by the mining company. The employment parameter is assigned a relative weighting of 20%.

Some underground mines employ more people compared to surface or shallow mining operations. The total number of employees in the mining industry (both surface and underground) was 458,954 in 2021 (see Table 2.6).

Table 2.6: Employment in the mining industry between 2011 and 2021

Year	Total	Gold	PGMs	Diamonds	Chrome ore	Iron ore	Manganese	Non-ferrous metals	Coal	Industrial minerals	Other minerals
2011	512,874	144,799	194,745	12,047	16,911	22,360	7,460	_	78,580	13,013	22,961
2012	524,869	142,200	197,752	12,332	19,762	23,380	8,685	_	83,244	13,795	23,719
2013	509,909	131,738	191,260	13,579	18,358	21,127	9,842	15,539	88,039	13,623	6,805
2014	492,931	119,007	186,864	15,356	18,658	21,794	9,971	15,816	86,106	13,031	6,330
2015	480,205	115,029	186,465	18,313	18,450	20,554	8,639	16,414	77,747	12,866	5,727
2016	458,291	116,572	172,556	18,789	15,449	16,651	7,242	14,754	77,259	13,222	5,797
2017	463,901	112,901	172,760	18,038	16,968	17,510	7,780	16,325	82,372	13,029	6,219
2018	456,438	100,189	167,041	16,361	18,935	18,613	9,352	17,466	89,647	12,712	6,121
2019	460,015	92,916	168,102	15,252	20,901	19,769	11,143	19,593	94,297	12,195	5,847
2020	452,866	91,649	164,703	13,939	19,274	20,469	12,198	19,246	91,649	11,530	5,237
2021	**458,954**	**93,998**	**171,568**	**12,900**	**18,599**	**21,427**	**13,290**	**17,953**	**92,670**	**11,551**	**4,998**

Source: MCSA (2021)

2.5.9. Community

Local communities and employees are important for the success of the mining operation. Involving a community in the mining industry will ensure that a mine secures a social licence to operate. Mining companies are required to submit a social and labour plan (SLP) according to Section 23 of the MPRDA and charter contemplated in Section 100 for their operations, which is a social contract towards sustainability and development of the community (MPRDA, 2002).

Companies contribute towards the corporate social investment which is mostly directed to the communities. The community parameter is assigned a relative weighting of 15%.

Local communities are affected by mining activities due to the nature of the mining operations, starting from exploration to mine rehabilitation. Factors such as health, safety (fatalities), environment (pollution, noise, and dust), land and water, disputes, riots, sustainability and socio-economic issues continue to affect the community (Kitula, 2005). A tripartite team which includes the community, government and mining companies, is responsible for addressing and resolving concerns due to mining activities. Power relations must be managed properly between the government, community and mining companies to ensure smooth operation of the mine.

2.5.10. Mining expertise and equipment

Most of the African countries endowed with mineral resources do not manufacture their own mining equipment. Mining requires knowledge, technology and facilities, including specialised skills. The equipment and technology are imported to the country from international manufacturers (e.g., USA, Asia, Europe) (StatsSA, 2022).

Expertise, machinery, and technology contribute toward the comparative and competitive strategies, which will result in the growth of the industry

(Olvera, 2022). The manufacturing industry contributes more to the economy of the country when mineral resources are processed and beneficiated in the country. This further contributes to job creation and skills training for the local communities. The knowledge of experts and mining equipment parameter is assigned a relative weighting of fifteen percent. State-owned research and development institutions can promote local processing, refining, and manufacturing of the products.

2.5.11. Investment

Several mining life cycle stages, such as exploration, feasibility studies, production, processing, beneficiation and rehabilitation, are considered when starting a mining operation. To start a mining project capital investment is required. Exploration and mining activities are capital-intensive (Gylfason, 2001).

Exploration strategy of the government is focused on economic growth, social benefits and environmental care through good governance. It aims to secure a minimum of 5% share in global exploration expenditure within a period of five years (DMRE, 2022).

A sustainable mining industry requires exploration leading to the discovery of new deposits and a mining industry for production activities. Therefore, access to capital is a requirement for mining. In 2022, more than half of exploration expenditure for Africa came from Canada and Australian and was estimated at 52% (see Figure 2.6) (S&P, 2022). This could be due to perceptions of risk in Africa and mostly exploration capital is from Canada and Australia.

Incentives must be used to attract investments and development of public markets. South Africa’s share of the exploration budget declined from 35% in 2002 to 8% in 2018 (S&P, 2019) due to lack of investment and in 2022 South African companies’ budget increased to approximately $8 million (S&P, 2022). Other African countries such as the Democratic Republic of the Congo (DRC), Burkina Faso, Ghana, Ivory Coast and Mali attract more exploration investment compared to South Africa.

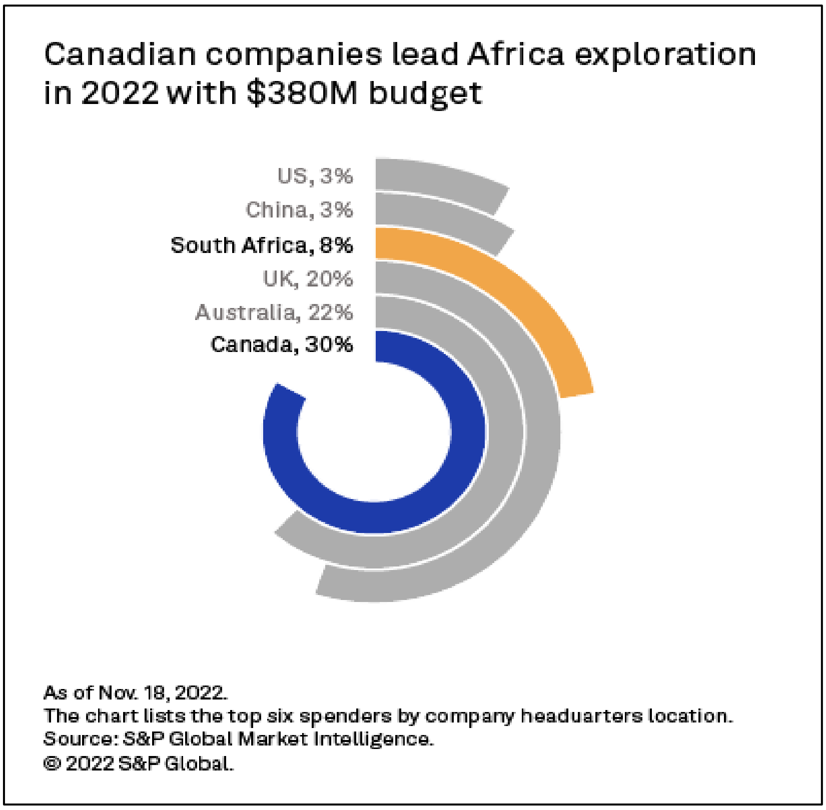


Figure 2.6: World exploration expenditures and budgets in 2022

There must be a balance between interested groups, namely, investors, government and mining companies to ensure capital investment in the mining industry. Investors are interested in return on the investment. Investment in the mining sector will be affected by prices of electricity, as well as port and rail tariffs for export.

2.5.12. Policy

The government is responsible for creating a favourable business environment to attract investment, sustainability as well as the well-being of its citizens. This can be achieved through favourable and clear policies. Platinum (e.g., beneficiation and platinum coin) and diamond (e.g., diamond export levy Act) industries have identified several initiatives to promote the industries’ potential. Government should provide feasible criteria for companies to meet the requirements for incentives as it will promote investment.

Larger mining companies account for most of the total exploration spending (PWC, 2023). Certainty is required in mining to ensure a stable and predictable policy and regulatory framework. The policy and regulation parameter is assigned a relative weighting of 15%.

A successful mining industry requires competent administrators, reliable systems and a competitive policy environment. The application for mining permits and rights, monitoring of mining activities by inspectors, as well as documentation require competent administrators. A reliable and easily accessible system is important to attract investment. Requirements of the Mining Charter III should be favourable and create conducive environment to attract investment.

The government should be familiar and recognise the importance of investing into the country's geological endowment such as the Council for Geoscience. The Council for Geoscience should lead the geological research, regional surveys and mapping, as well as recording of historical exploration data which should be accessible and made freely available to prospective explorers.

Further, the government should develop and adopt an internationally competitive policy environment because of the non-renewable nature of resources and status in the global market. Clarity and certainty are crucial in the policy framework and regulation, as well as compliance, taxation, discretionary powers, vulnerability and opportunities for intervention.

The aspirations and plans of the government should be clearly articulated and updated in the National Development Plan in order to achieve maximum benefits from the mineral resources for the country and its citizens (NDP, 2012).

2.5.13. Labour and costs

The South African mining industry has a history of intensive manual labour. Previously, a lack of education, skills and technology led to high employment of unskilled labour in the industry. Employment numbers increased from 452,866 in 2020 to 458,954 employees in 2021 (MCSA, 2021).

Main issues such as costs, strikes or protest actions, salary and skills affect profitability and survival of mining operations. These issues are pertinent in the successful mining and utilisation of mineral resources in the country. Labour and costs parameter is assigned a relative weighting of ten percent. Employee earnings increased from R151.7 billion in 2020 to R153.8 billion (MCSA, 2021). Coal example below shows (see Figure 2.7) the average labour costs and share in total coal mining costs in selected countries between 2018 and 2020 (IEA, 2021). South Africa is the lowest at 17% in 2020 and Australia is the highest at 33%.

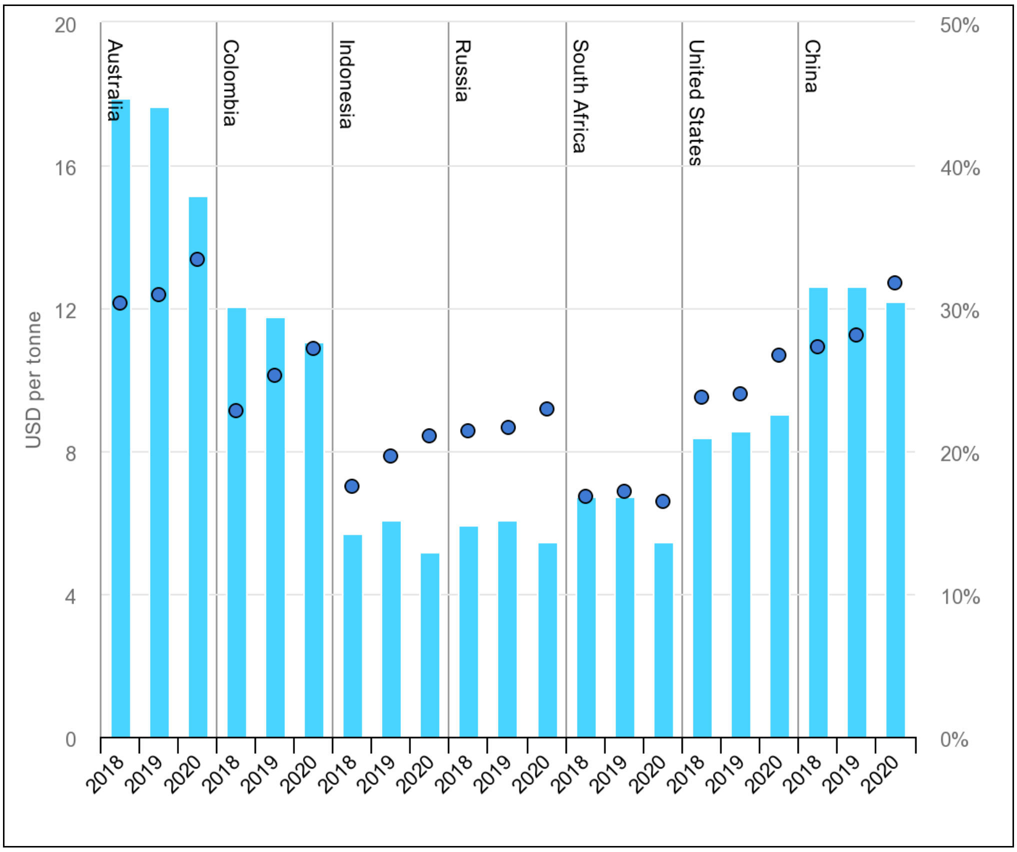


Figure 2.7: Average labour costs and share in total coal mining costs in selected countries between 2018 and 2020.

The government should adopt favourable policies and develop a favourable environment for both the employees and employers. A balance is required to ensure that labour costs do not render mining operations unprofitable, and that workers are not exploited.

2.5.14. Environment and society

Mining activities affect the environment by its nature. Land, water and communities around the mining operations are affected as a result of pollution, noise, dust, contamination, resettlement and emissions. The strict implementation of environmental regulations makes exploitation and processing of minerals difficult and more costly. Environment and society parameter is assigned a relative weighting of 15%.

Mining companies are required to conduct environmental studies to assess the impact and remediation strategies including rehabilitation plans to ensure sustainability of the environment (MPRDA, 2002). The country must adopt international standards and commitments in order to be competitive and contribute to environmental sustainability.

It is a requirement that at the end of the life of a mine the environment should be rehabilitated (MPRDA, 2002). Some mining operations continue to do some rehabilitation activities during the process of mining from exploited mining blocks of ground (i.e., overburden and ore). In the previous studies farmers have indicated that the soil was not the same for agricultural use as it was before mining (Yang et al, 2019). Compensation is offered to farmers and communities displaced from their places of settlement and farming.

2.5.15. Infrastructure

The geographical location of mineral resources to the market and point of utilisation is important. Mineralisation of the ore bodies is naturally controlled, and minerals are deposited in different location according to the mode of the depositional environment (Wilson et al., 1998). Transportation of mineral deposits to the point of utilisation and the market is through the roads, rail and ports. The development of this infrastructure is a requirement for the successful, thriving and competitive mining industry. Infrastructure parameter is assigned a relative weighting of 10%.

2.6. South African minerals and reserves

Geological time and formation favoured South Africa, as the country has the oldest Archean rock formation which is rich in gold, iron and manganese (Kessel, 1990). South Africa has a plan for the mineral resources in the five value chains (DMRE, 2011). The reserves for the minerals in 2021 (DMRE, 2021; StatsSA, 2021; MCSA, 2021) are summarised in Table 2.7.

Table 2.7: South African mineral reserves in 2021 including world ranking and location of major reserves.

Commodity	Substitutes	Units	South Africa's reserves	World		Location of major reserves		
				Ranking	%	1st	2nd	3rd
Chromium	No substitute in stainless steel, leading end use, or in superalloys.	Mt	200,000	1	35	Kazakhstan	South Africa	India
Coal	Coal to liquids, power generation, chemicals manufacture.	Mt	53,156	6	3.5	United States	Russia	Australia
Copper	Aluminium, titanium, and steel.	kt	11,000	11	1.0	Chile	Australia	Peru
Fluorspar (Cof)	Synthetic fluorspar could potentially be recovered by the US Department of Energy.	kt	41,000	3	13.0	Mexico	China	South Africa
Gold (metal)	Generally, palladium, platinum, and silver may substitute for gold in industrial applications	t	2,700	4	5.1	Australia	United States	Russia
Iron ore	No substitute	Mt	640	11	0.8	Australia	Brazil	Russia

Commodity	Substitutes	Units	South Africa's reserves	World		Location of major reserves		
Lead (metal)	Depending on application substitutes include tin, steel, zinc, and plastics	kt	300	Outside the world's top ten	0.3	Australia	China	Russia
Manganese (metal)	No satisfactory substitutes	Mt	520	1	40.0	South Africa	Australia	United States
Nickel	Low-nickel, duplex, or ultrahigh-chromium stainless steels; titanium alloys	Mt	3,700	*	0.04	Indonesia	Australia	Brazil
Platinum group metals	Palladium	kt	63,000	1	91.3	South Africa	Russia	Zimbabwe
Phosphate rock (contained concentrates)	There are no substitutes for phosphorus in agriculture	kt	1,400,000	6	2.0	Morocco and Western Sahara	China	Algeria
Rare earths	Substitutes are available for many applications but generally are less effective	t	790,000	11	0.7	China	Vietnam	Brazil
Titanium minerals	Ilmenite, leucoxene, rutile, slag, and synthetic rutile	Mt	35	5	4.5	Australia	China	India

Commodity	Substitutes	Units	South Africa's reserves	World		Location of major reserves		
(metals)								
Uranium (metal) Metal, up to U.S 5 80/Kg)		t	279,100	6	5.2	Australia	Kazakhstan	Canada
Vanadium (metal)	Manganese, molybdenum, niobium (columbium), titanium, and tungsten	kt	3,500	4	15.9	China	Russia	Australia
Vermiculite	Depending on application, expanded perlite, expanded clay, shale, slag, and slate	kt	14,000	2	N/A	USA	South Africa	Brazil
Zinc (metal)	Aluminium alloys, cadmium, paint, and plastic coatings, magnesium-base alloys	kt	14,000	N/A	N/A	Australia	China	Mexico, Russia
Zirconium minerals (metals)	Chromite, olivine, niobium (columbium), stainless steel, and tantalum	kt	6,500	2	10.4	Australia	South Africa	Mozambique

Source: MCSA (2021); DMRE (2021); USGS (2021)

The South African economy requires sufficient electricity in order to optimally exploit the mineral reserves. A shortage of electricity affects many sectors such as mining, manufacturing, agriculture, commercial and residential sectors.

Electricity consumption in different sectors has changed from 2016, where industry was 40.9%, residential (36.8%), commercial (11.4%) and transportation (2.7%) whereas in 2019, industry was 56%, residential (19%), services (14%), and transportation was 2% (DMRE, 2016; Statista, 2023). Consumption of electricity in different sectors in South Africa is indicated in Figure 2.8 where the industrial sector consumes more electricity than any other sector at approximately 56%. Electricity usage in 2022 (CGS, 2023) was dominated by coal fired power generation where coal contributed 80%, nuclear (4.6%), renewables (13.7%) and diesel (1.6%). There is currently high dependence on the import of liquid fuels because the current capacity does not meet national and export demand (Department of Energy, 2016). Mineral resources produced in the country are useful in ensuring a steady and sustainable supply of energy for growth and development.

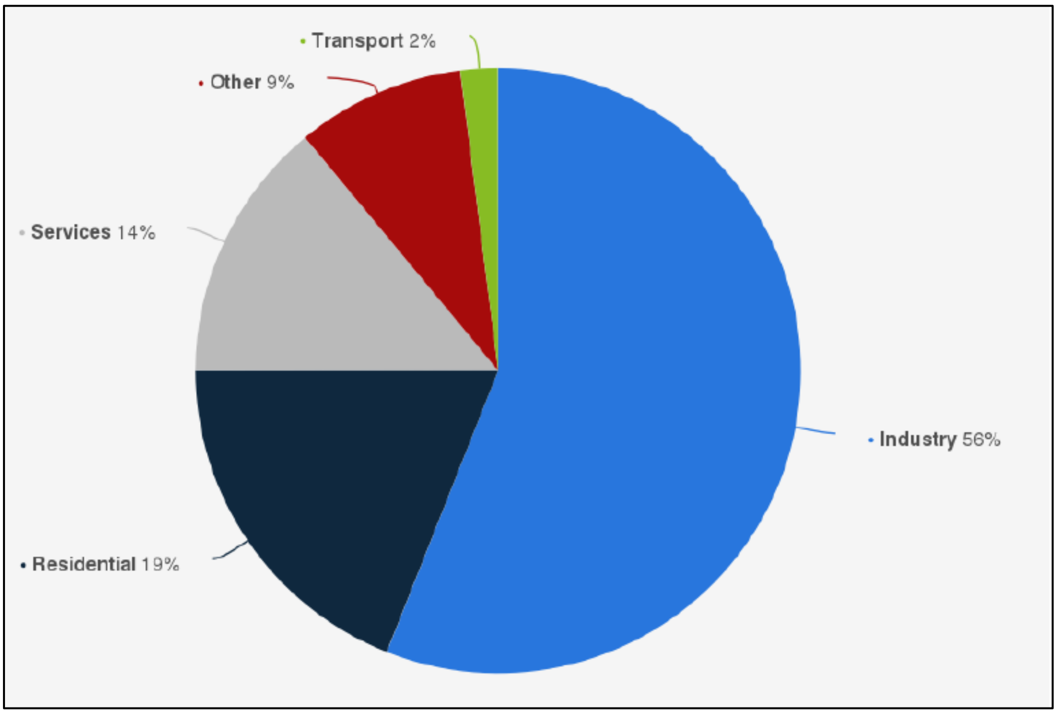


Figure 2.8: Electricity consumption in different sectors in South Africa

Minerals are important to the economy of the country. These minerals contribute to the gross domestic product, energy supply, employment, corporate income, exports, royalties and local communities. Some minerals contribute more to the economy such as PGM's, coal, iron ore, gold, manganese, chrome ore and diamonds and others such as silver, copper, lead, nickel, zinc are mostly contributing more than 70% of the export sales (see Table 1.1). The contribution of future technology and energy minerals such as REE, uranium, lithium, cobalt and aluminium are critical for the economy. Minerals are selected according to their economic contribution, abundance and utilisation in the country.

2.6.1. Coal

Coal was discovered in South Africa in the 1800's. It was first discovered in KwaZulu-Natal, Mpumalanga and the Eastern Cape provinces, and documented between 1838 and 1859. The first mining of coal took place near Molteno in the Eastern Cape in 1870 (Jeffrey, Henry and McGill, 2015). The demand for coal increased after the discovery of diamonds and gold which led to the opening of new mines in Vereeneging in 1879 and Witbank in 1895 (Jeffrey et al., 2015). Other future coal mining developments started in KwaZulu-Natal, Gauteng and Mpumalanga which was later followed by the Free State and Limpopo (Jeffrey et al., 2015).

Coal deposits are divided into 19 coalfields. The coalfields of South Africa are found in the rocks of the Karoo Basin (see Figure 2.9). The Karoo Supergroup is divided into four main lithostratigraphic units: Dwyka, Ecca, Beaufort, and Stormberg groups. The Stormberg group is sub-divided into the Molteno, Elliot and Clarens formations (Cadle et al., 1993).

The quality of the coal in the country is important for manufacturing and power generation. Clean coal technologies for power generation are not sufficiently implemented in South Africa and will need to be installed soon. Some elements within coal such as sulphur are important for the quality because of its effect on the environment.

Energy resources for the country can be derived from coal, coal bed methane, shale gas, uranium and geothermal energy which will contribute to the economy (Hancox and Gotz, 2014).

All coals contain mineral matter (called ash when combusted) that can be removed through physical cleaning (beneficiation) to improve quality and usage. In coal preparation and beneficiation, it is vital to understand coal characteristics, liberation processes of mineral matter, separation of ash material from coal and disposing of ash or waste material to the environment in a responsible manner (EIA, 2007).

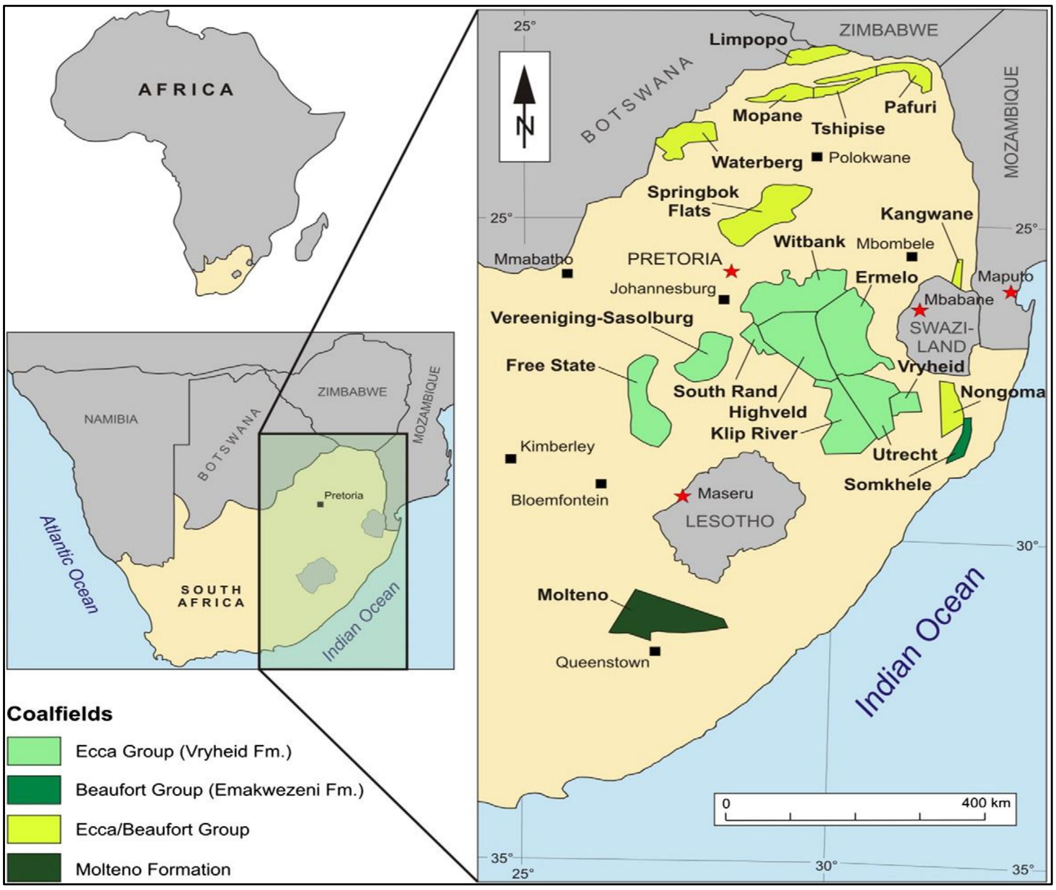


Figure 2.9: Coalfields of South Africa

Some challenges must be addressed to enjoy the benefits of this coal resource. These challenges include infrastructure, regulatory and policy frameworks. In terms of the infrastructure, it is important to have a new coal line to unlock coal deposits in the Waterberg, to extend existing coal lines in the central basin, and to upgrade the Richards Bay Coal Terminal coal lines.

Other challenges include ensuring domestic security of supply of coal for existing power stations, a more comprehensive coal mining plan and accessing the Waterberg coalfield by creating a new heavy-haul road (The National Planning Commission, 2012). Coal fields can be utilised to provide thermal electricity generation and carbon capture and storage.

Globally, coal is still produced, supplied and consumed in large quantities. The highest proved coal reserves are from the US with the reserves-to-production (R/P) ratio of 365 (BP Stas Review, 2019). Table 2.8 shows the total world share reserves for the US, Russia, Australia, China, India and South Africa.

Table 2.8: Total coal reserves in 2018 by country

Million tonnes	Anthracite and bituminous	Sub-bituminous and lignite	Total	Share of total	R/P ratio
China	130 851	7 968	138 819	13.2%	38
United States	220 167	30 052	250 219	23.7%	365
Indonesia	26 122	10 878	37 000	3.5%	67
Australia	70 927	76 508	147 435	14.0%	304
Russia	69 634	90 730	160 364	15.2%	364
South Africa	9 893	0	9 893	0.9%	39

Source: BP Stas Review (2019)

The top coal-producing countries in 2018 (in million tonnes oil equivalent) are China (46.7%), United States (9.3%), Indonesia (8.3%), India (7.9%), Australia (7.7%), Russia (5.6%), and South Africa (3.7%). The percentages indicate the total world production share (BP Stats Review, 2022) (refer to Table 2.9).

Table 2.9: Total world production share in 2018 and 2021 by country

Coal: Production*												Growth rate per annum		Share	
Exajoules	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2021	2011-2021	2018	2021
China	77.53	78.44	79.32	78.05	76.59	70.82	73.17	76.87	79.76	80.51	85.15	6.0%	0.9%	46.7%	50.8%
US	22.27	20.72	20.05	20.33	17.99	14.70	15.66	15.40	14.29	10.73	11.65	8.9%	-6.3%	9.3%	7.0%
Indonesia	8.72	9.52	11.70	11.30	11.39	11.25	11.38	13.76	15.20	13.91	15.15	9.2%	5.7%	8.3%	9.0%
Australia	10.26	11.13	11.97	12.81	12.80	12.83	12.50	13.09	13.18	12.18	12.43	2.4%	1.9%	7.7%	7.4%
Russia	6.60	7.05	7.25	7.39	7.80	8.12	8.62	9.23	9.23	8.42	9.14	8.8%	3.3%	5.6%	5.5%
South Africa	6.00	6.14	6.08	6.20	5.96	6.01	5.97	6.01	6.02	5.82	5.55	-4.3%	-0.8%	3.7%	3.3%

Source: statistics are taken from national statistical agencies, international organisations, and other proprietary sources.
* Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), and lignite and brown (sub-bituminous) coal, and other commercial solid fuels. Includes coal produced for coal-to-liquids and coal-to-gas transformations.

The coal that has been produced is consumed in different countries according to their required quantities. The countries with the highest coal consumption in 2018 are China (50.5%), India (12.0%), United States (8.4%), Japan (3.1%), Russia (2.3%), and South Africa (2.3%) of the total of the world consumption share (BP Stats Review, 2022). In 2021, the countries with the highest world consumption share are China (53.8%), the United States (6.6%), Indonesia (2.0%), Russia (2.1%), and South Africa (-2.2%) (BP Stats Review, 2022) (see Table 2.10).

Table 2.10: Total world consumption share in 2021 by country

Coal: Production*												Growth rate per annum		Share
Exajoules	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2021	2011-2021	2021
China	79.71	80.71	80.43	82.48	80.92	80.19	80.56	81.05	81.70	82.38	86.17	4.9%	0.8%	53.80%
US	19.70	17.42	18.08	18.04	15.58	14.26	13.87	13.28	11.34	9.2	10.57	15.2%	-6.0%	6.60%
Indonesia	1.96	2.03	1.78	1.88	2.14	2.23	2.39	2.84	3.41	3.25	3.28	1.2%	5.3%	2.00%
Australia	2.13	2.00	1.89	1.88	1.95	1.94	1.88	1.83	1.75	1.69	1.63	-3.1%	-2.6%	1.0%
Russia	3.94	4.12	3.79	3.67	8.86	3.74	3.51	3.63	3.57	3.29	3.41	4.0%	-1.4%	2.10%
South Africa	3.79	3.70	3.70	3.75	3.52	3.78	3.72	3.53	3.76	3.56	3.53	-0.5%	-0.7%	-2.2%

* Commercial solid fuels only, i.e., bituminous coal and anthracite (hard coal), and lignite and brown (sub-bituminous) coal, Source: statistics are taken from national statistical agencies, and other commercial solid fuels. Excludes coal converted to liquid or gaseous fuels, but includes coal consumed international organizations, and other proprietary sources. in transformation processes.

The developed countries still utilise coal and it is contributing to their economies, also in the form of employment. In the US, the total mine revenue of production sales of coal from 2013 to 2016 was $100,000 (million dollars) it was estimated at $24,500 Million USD in 2017. Also, from 2013 to 2016 approximately 225,000 production workers were employed in coal mining, while it was estimated at 42,000 in 2017. The average weekly earnings of production workers in coal mining in 2016 was $1,336 and in 2017 was estimated at $1,430 (MCSA, 2018). Figure 2.10 shows that coal is still important for energy consumption in the US through to 2050 (x-axis is the year and y-axis is quadrillion British thermal units. Figure 2.11 shows the electric power sector demand for coal (x-axis is the year while y-axis is million short tons) (EIA, 2018).

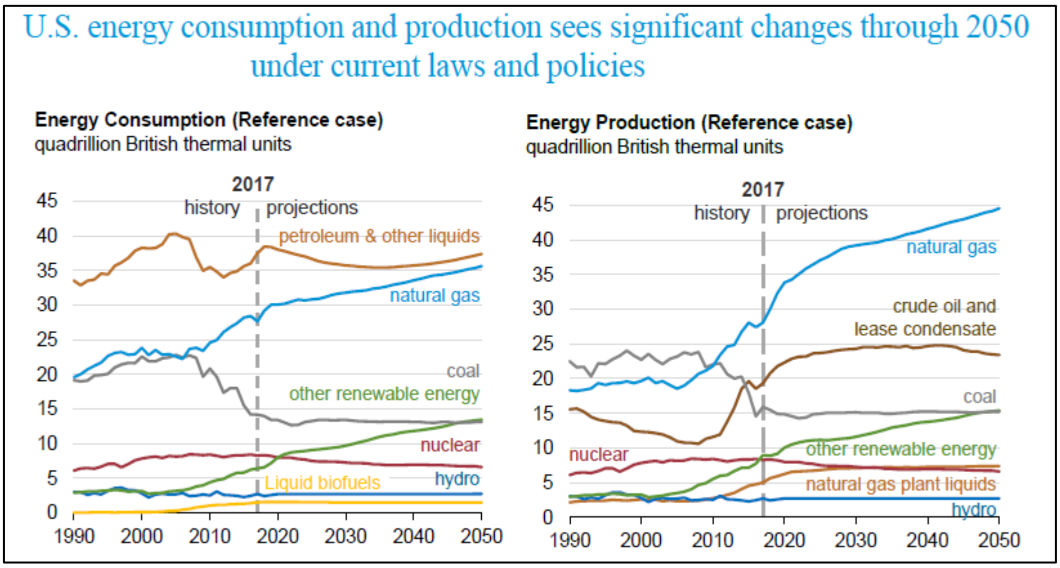


Figure 2.10: Energy consumption and production through 2050 for coal in the US

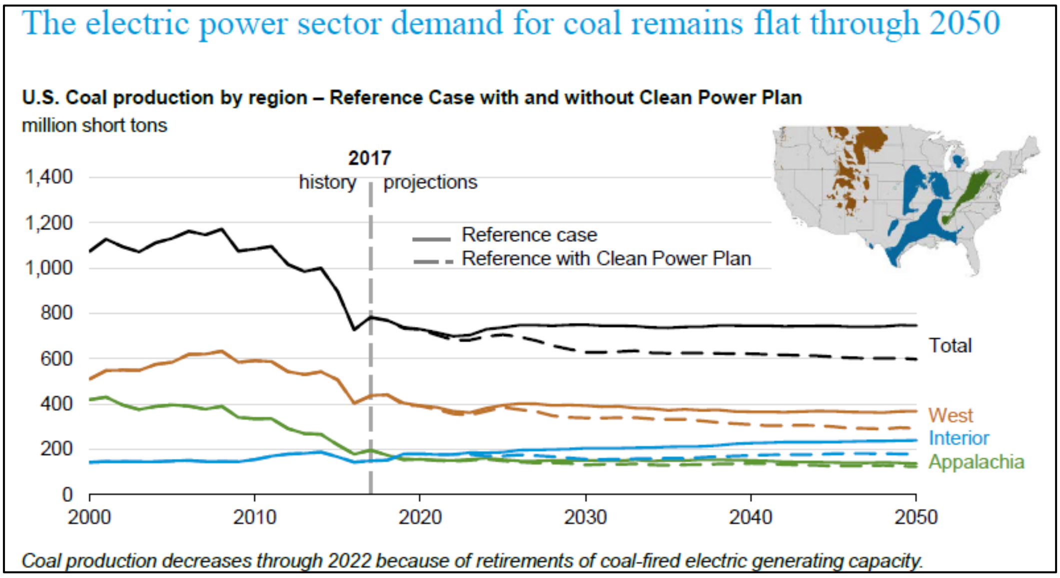


Figure 2.11: Electric power demand for coal in the US

The growing population and economies will result in a high demand for power generation to meet the needs of the population. Developed countries continue to utilise coal in their energy mix, but developing countries are encouraged to reduce emissions.

The South African government has agreed in 2009 to reduce emissions by 42% by 2025, which means that drastic steps should be taken to address the aging power stations in the country (South African Government). Meridian economics, backed by development finance institutions and private funders, have made a proposal to lend Eskom $11 billion (R161.1 billion) below commercial rates on condition that it accelerates the closure of coal plants with high gas emissions and make way for renewable energy (South African Government). South Africa needs global climate finance transactions to ensure a cleaner and more resilient energy future.

2.6.2. Platinum group metals

In Southern Africa, the large mafic to ultramafic layered complexes are found in the Kaapvaal and Zimbabwe cratons. The two large well-known complexes in Southern Africa are the Great Dyke in Zimbabwe and Bushveld Complex in South Africa. The largest and most economical is the Bushveld Igneous Complex (BIC) estimated at 66,000 km^2 in area. Platinum in South Africa is hosted within the Bushveld Complex. Mafic rocks of BIC are rich in platinum group elements (PGEs), chromium and vanadium. The PGEs were recovered in early 1919 from the gold mines in Ekurhuleni, later on in the Witwatersrand basin, and where recovery of PGMs improved. The discovery of platinum in South Africa is dated back to 1924 on Maandagshoek in Mashishing, formerly known as Lydenburg. Sampling was conducted by Lombard at the request of Hans Merensky from the pyroxenitic layers which was initially termed Lombard reef yielded high values (Wilson et al., 1998). This reef was later named Merensky reef, which became the most important platinum producing layer. The mining of Merensky reef started in the Rustenburg area in 1929. Other platinum-bearing reefs are chromitite and platreef (Wilson et al., 1998). Bushveld complex hosts the largest resource of PGMs in the world (Wilson and Anhausser, 1998).

The Bushveld complex hosts approximately 80% of platinum bearing ore, found in the northern portion of South Africa. It is the world's largest layered intrusion. It is divided into the western, eastern, northern and southern limbs, as indicated in Figure 2.12 with the main Platinum operations.

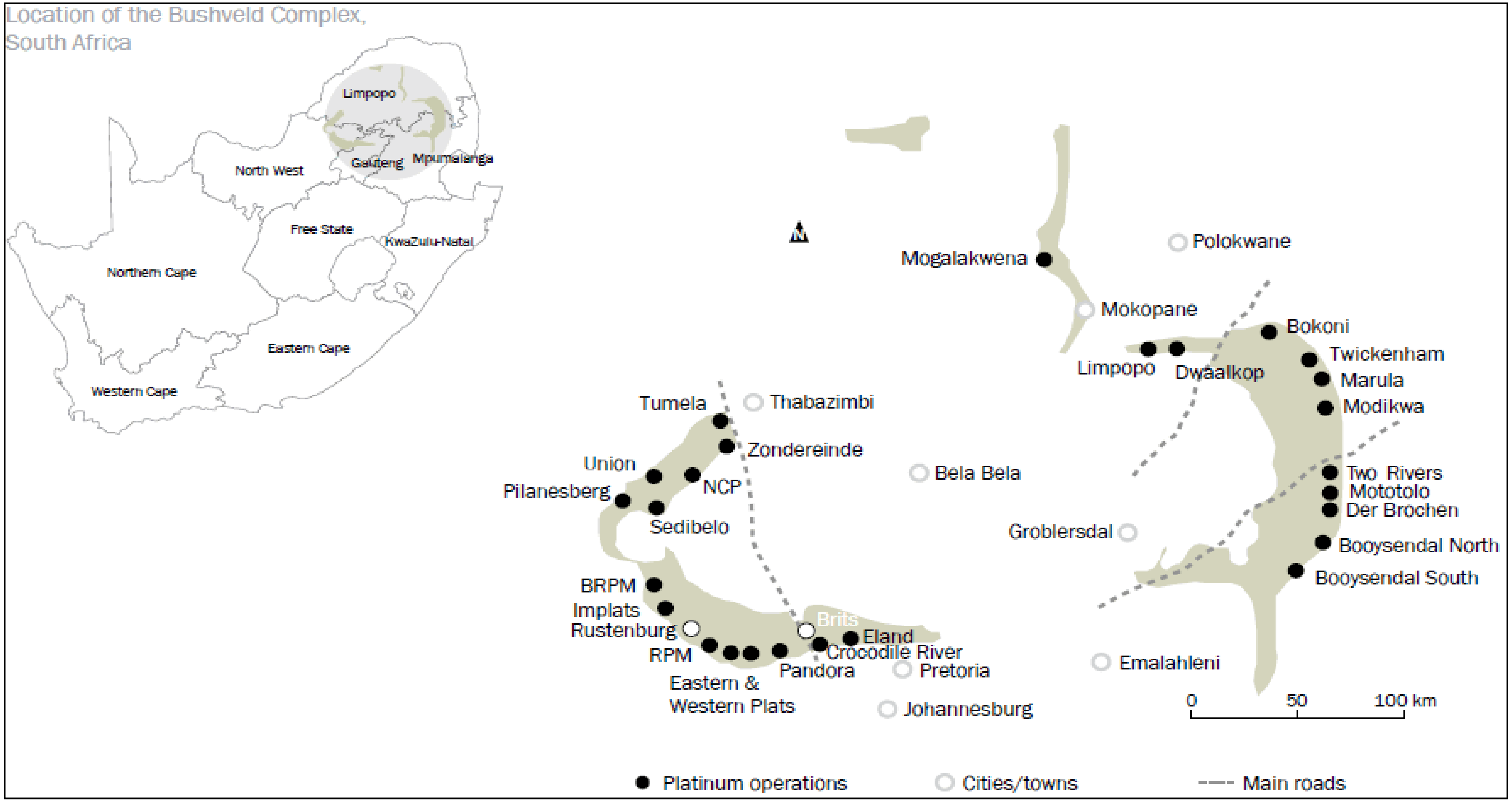


Figure 2.11: Bushveld Complex showing the limbs

2.6.2.1. Application and uses of PGMs

PGMs are platinum (Pt), palladium (Pd), iridium (Ir), rhodium (Rh), ruthenium (Ru) and osmium (Os). These PGMs have good properties such as high density, strength, catalytic properties and high melting temperature, which make them useful in high technology applications. The minerals are utilised in the industrial, chemical, electrical, electronics and manufacturing sectors.

The main use in the beginning was in the petroleum industry as a catalyst to increase the octane rating of petroleum and to manufacture primary feedstocks for the growing plastics industry. It was used for jewellery, which increased the demand (MCSA, 2017).

South Africa plays a major role in world reserves for some of the minerals. PGMs are six precious metallic elements that are important for our daily use; namely, platinum, palladium, rhodium, iridium, ruthenium, and osmium.

These metallic elements are used to reduce gas emissions such as catalytic converters for computer hard disks, mobile phones, aircraft turbines, glass, nitric acid, silicon, jewellery and investment (see Table 2.11). PGMs are also important to the hydrogen industry for fuel cell technology.

Table 2.11: Applications and uses of platinum group metals in different sectors.

Mineral commodity	Platinum-group metals
Aerospace (non-defence)	*Jet engines (casting, coatings)
Defence	N/A
Energy	*Petroleum catalysts *Land-based turbines *Fuel cells *Autocatalysts
Telecommunications and electronics	*Hard-disk drives *Capacitors *Flat-panel displays

Transportation (non-aerospace)	*Autocatalysts *Fuel cells *Automotive components
Other	*Chemical catalysts *Medical applications *Refractory crucibles *Metallurgical applications *Integrated circuits

Source: DMRE (2016)

The application and uses of platinum across many sectors continue to create and drive demand. In 2010, the highest demand was in the autocatalytic usage at 97.2 metric tons, which was affected by recycling and electric engines. The total demand for platinum from different sectors, namely, automotive, jewellery, industrial and investment was 10,251,000 ounces (see Table 2.12) (Matthey, 2023).

Power problems create a demand opportunity for platinum. Electricity can be generated from fuel cell technology. The first building baseload fuel cell of 100kW in South Africa was installed at the Mineral Council of South Africa (MCSA) building in Johannesburg. It supplies electricity to the whole building and not from the Eskom power grid. In fuel cell technology, electricity is generated from hydrogen fuel and oxygen (MCSA, 2017).

Several options such as using the platinum fuel cells to run the platinum refinery at the plant and locomotives and load haul dumpers at the mine production were to be considered.

Table 2.12: Platinum demand according to applications and uses in 10 years

Demand ‘000 oz	**2021**	**2022**	**2023**
Automotive	8,499	8,449	8,251
Jewellery	88	87	88
Industrial	1,647	1,510	1,469
Investment	17	-109	25
Total demand	10,251	9,937	9,833

2.6.2.2. Reserves and resources

South Africa is endowed with mineral resources and is highly ranked amongst the top countries with abundant mineral reserves. Table 2.7 shows different commodities and South African reserves compared to other countries (DMRE, 2021). Some of the precious minerals produced are gold, platinum group metals, diamonds and silver, including base minerals such as chrome, copper, iron ore, lead concentrate, manganese, nickel, zinc, coal and other non-metallic minerals (Wilson et al., 1998).

2.6.2.3. Production and supply

The increased costs and low commodity prices (i.e., Platinum prices decreased by 7.3%, from US$1,574 in 2008 to US$880 in 2018) have affected the production of the PGMs (see Figure 2.13). Platinum production in 2018 was 259 000 tonnes, which has decreased by 1.2% compared to the previous year (MCSA, 2018). Total sales were R96.1 billion and the value of percentage exported is 89% (MCSA, 2018).

The decrease in production is due to some of the structural challenges in the industry, such as increased recycling, substitution of rhodium out of catalytic converters, substitution of platinum out of gasoline as catalytic converters, lack of investment, and operational costs. There was huge contribution from platinum sales in 2021 as compared to the other years from 2010 (see Table 2.13) (MCSA, 2021).

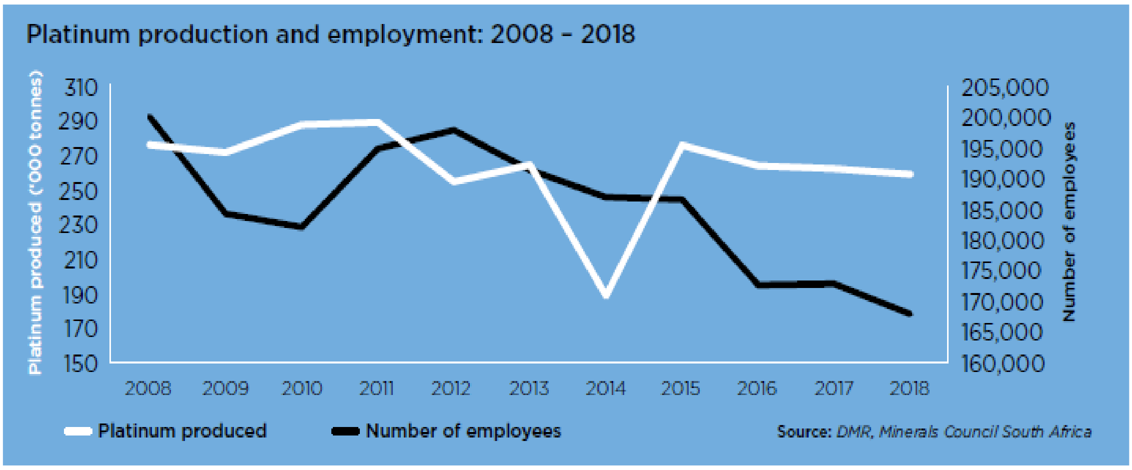


Figure 2.12: Total platinum produced and people employed between 2008 and 2018.

Table 2.13: Total platinum production and sales between 2010 and 2021

Production		Local sales		Export sales		Total sales	
Year	**Tonnes**	**Tonnes**	**R'000**	**Tonnes**	**R'000**	**Tonnes**	**R'000**
2010	287	–	7,892,570	244	65,894,341	–	73,786,910
2011	289	–	10,619,219	244	73,234,047	–	83,853,266
2012	254	–	8,285,235	211	60,918,939	–	69,204,174
2013	264	28	8,886,103	239	75,348,535	266	84,234,637
2014	188	28	10,644,402	202	66,860,760	230	77,505,163
2015	276	32	11,149,886	254	82,988,098	286	94,137,984
2016	264	31	11,093,840	250	85,318,461	282	96,412,301
2017	262	32	11,966,660	251	85,069,237	283	97,035,896
2018	271	24	10,668,195	244	94,228,661	268	104,896,855
2019	268	16	11,441,132	227	124,585,015	243	136,026,147
2020	226	15	17,189,499	178	173,241,908	193	190,431,408
2021	**285**	**13**	**25,253,878**	**265**	**321,271,671**	**277**	**346,525,549**

Source: MCSA (2021)

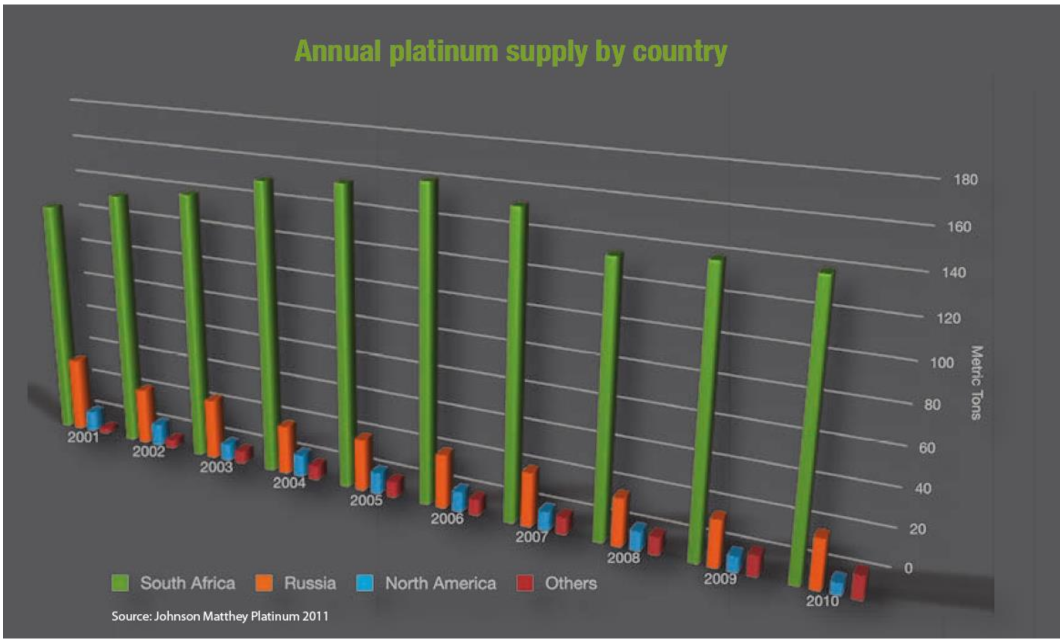


Figure 2.13: Total annual supply of platinum by country from 2001 to 2010

The major countries in the global platinum production in 2018 were South Africa (110 Mt), Russia (21 Mt), Zimbabwe (14 Mt), Canada (9.5 Mt), the US (4.1 Mt), 3and other countries contributed (6.1 Mt), in metric tonnes (MCSA, 2018). South Africa remained the major producer between 2001 and 2010 (see Figure 2.14) (MCSA, 2010).

In terms of supply by country in 2021, major suppliers were South Africa (82.6 Mt), Russia (79.6 Mt), North America (30.4) and Zimbabwe (12.8). The total supply in 2021 was 209.9 Mt (see Table 2.14) (MCSA, 2021).

Table 2.14: Total platinum supply by countries between 2016 and 2021

Supply tonnes (Mt)	2016	2017	2018	2019	2020	2021
South Africa	80	79.2	79.1	80.5	61.5	82.6
Russia	86.5	76.3	92.6	92.9	82	79.6
North America	28.5	29.7	30.4	31.4	29.7	30.4
Zimbabwe	12.3	12	12.2	11.8	12.8	12.8
Others	4	4.1	4.2	4.4	5.6	4.5
Total supply (Mt)	**211.3**	**201.3**	**218.5**	**221**	**191.6**	**209.9**

Source: MCSA (2021)

The mining industry produced 221 million ounces of PGMs valued at R1.2 trillion between 1980 and 2015. In 2017, platinum produced was 253 tonnes, and the total sales was R94.1 bn (MCSA, 2017). In terms of direct employment, 175,770 people were employed, and the employee earnings were R48.0 billion. The royalties paid out were R0.8 billion. The total percentage of metals exported was 87% (MCSA, 2017).

2.6.2.4. Contribution to the economy

PGMs continue to contribute to the economy of the country. The contribution to the economy in 2021 was in the form of direct employment (171 568 employees), employee earnings (R67.3 billion), and royalties (R5,743 million) (MCSA, 2021). The total earnings and number of employees increased from 2001 to 2010 (see Figure 2.15) (DMRE, 2016). This industry in the downstream sector also contributes financially as well as indirectly through employment to the economy.

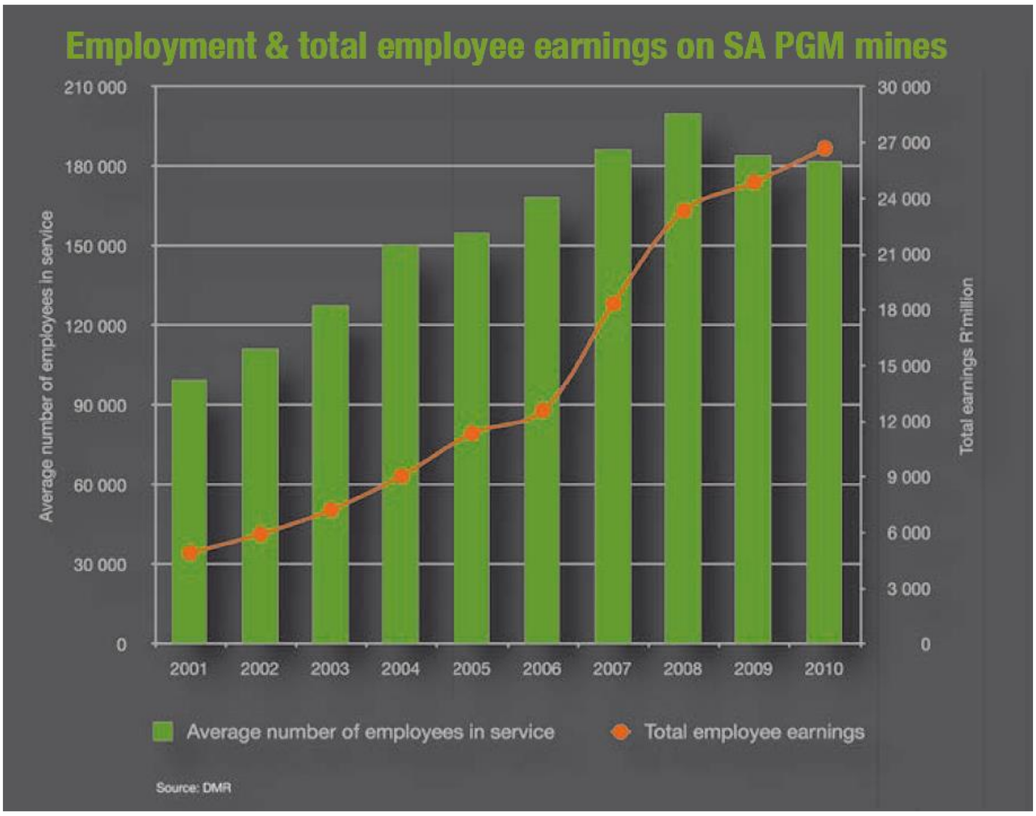


Figure 2.14: Employment and earnings in the platinum industry from 2001 to 2010

The platinum industry increased employment to 171,568 employees compared to 164,703 employees in 2020 and earnings increased from R61,1 billion to R67,3 billion in 2021 (Table 2.15) (MCSA, 2021). Total employment increased by 4.2% in 2021. Employment and sales in the platinum mines make a huge contribution in the economy.

Table 2.15: Employment and earnings in the PGM sector between 2011 and 2021

Year	Employment	Earnings (R'000)
2011	194,745	30,482
2012	197,752	34,393
2013	191,260	37,710
2014	186,864	35,652
2015	186,465	44,955
2016	172,556	45,926
2017	172,760	49,484
2018	167,041	51,412
2019	168,102	55,976
2020	164,703	61,083
2021	**171,568**	**67,312**

Source: MCSA (2021)

2.6.3. Manganese

Manganese is a base metal which is hard and brittle and has a crustal abundance of 0.1% (Wilson et al., 1998). It is the twelfth element. The mining of manganese in South Africa can be traced back to the early 1900s. Manganese was mined in Hout Bay near Cape Town and was later followed by the discovery of economic deposits in Postmansburg in the Northern Cape province in 1922 (Wilson et al, 1998). A rail link was constructed, and production started in 1930. Several deposits were discovered afterwards, which include discoveries in the Kalahari Manganese Field. This led to the opening of the Black Rock Mine in 1940 (Wilson et al., 1998). These deposits are mostly in the Northern Cape, North-West and Limpopo. There are some occurrences of manganese in different parts of South Africa.

2.6.3.1. Applications and uses of manganese

Manganese is mainly used in industrial and metallurgical applications, batteries and chemicals. It is also used in the manufacturing of steel, added in the form of ferromanganese, and serves as a sulphur fixing agent, a deoxidant, and to a limited extent as an alloying element (Wilson et al., 1998). Manganese can be used in different applications such as aluminium and steel production and light weight alloys (see Table 2.16) (DMRE, 2016).

Table 2.16: Applications and uses of manganese in different sectors.

Mineral commodity	Manganese
Aerospace (non-defence)	*Jet engines (superalloys) *Aluminium alloys
Defence	*Aluminium alloys
Energy	*Land-based turbines *Lightweight alloys *Rechargeable batteries
Telecommunications and electronics	N/A
Transportation (non-aerospace)	*Aluminium alloys
Other	*Speciality steel

Source: DMRE (2016)

2.6.3.2. Resources and reserves

Manganese resources found in South Africa are estimated at 40% of the world resources (DMRE, 2021). The reserves of manganese are 520 Mt (metric tonnes) and South Africa is ranked number one as the largest producer of manganese globally (see Table 2.7) (DMRE, 2021; USGS, 2021). Manganese is considered a strategic metal by most industrialised nations and has no satisfactory substitutes (Wilson et al., 1998).

2.6.3.3. Production and Supply

Manganese production in 2018 was 14.6 million tonnes (see Figure 2.16), which has increased by 1.66% compared to the previous year. The total sales were R43.2 billion, and the percentage value of manganese exported is 98% (MCSA, 2018). In 2021, production was 19.2 million tonnes, which increased by 18.3% compared to 2020 (Table 2.17). The supply for export and import sales increased by 4.9% to 16Mt and 14% to 2.5 Mt respectively when compared to 2020 (MCSA, 2021).

Production and supply can be increased further when some of the structural challenges in the industry such as shortages in electricity supply, limited port and rail infrastructure, and community and labour unrest can be addressed. Industrialisation will be constrained by electricity supply, required capacity, and operational costs.

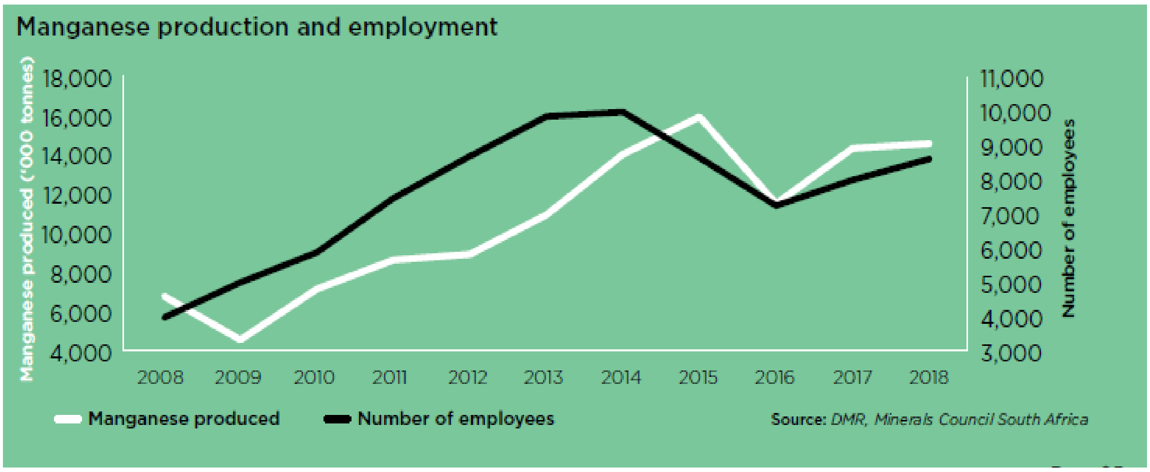


Figure 2.15: Manganese produced and people employed between 2008 and 2018

Table 2.17: Total Manganese production and sales between 2010 and 2021

Production		Local sales		Export sales		Total sales	
Year	**Tonnes**	**Tonnes**	**R'000**	**Tonnes**	**R'000**	**Tonnes**	**R'000**
2010	7,171,745	888,389	1,320,564	6,283,356	9,340,026	7,171,745	10,660,590
2011	8,651,842	1,158,712	1,325,213	7,493,130	8,569,854	8,651,842	9,895,067
2012	8,943,415	937,962	1,134,842	8,005,453	9,685,812	8,943,415	10,820,654
2013	10,957,133	1,140,248	1,506,434	9,816,885	12,969,545	10,957,133	14,475,979
2014	14,051,244	1,408,581	1,641,633	12,642,663	14,734,415	14,051,244	16,376,049
2015	15,952,416	1,015,415	860,474	14,937,001	12,657,775	15,952,416	13,518,249
2016	11,527,524	523,333	896,947	11,004,191	18,860,231	11,527,524	19,757,177
2017	14,349,888	766,150	1,726,702	13,583,738	30,614,192	14,349,888	32,340,893
2018	14,918,236	355,027	1,066,479	14,563,209	43,746,990	14,918,236	44,813,469
2019	17,002,978	661,442	1,751,826	16341536	43,280,475	17,002,978	45,032,300
2020	16,059,758	2,138,644	2,841,816	15,370,604	34,851,623	17,509,248	37,693,440
2021	**19,156,479**	**2,450,021**	**2,757,122**	**16,021,176**	**34,341,810**	**18,471,197**	**37,098,932**

The total production in 2018 was 16.6 Mt, that resulted in total sales of R43.2 billion. The total percentage value of the manganese exported was 98% (MCSA, 2018).

2.6.3.4. Contribution

The contribution of manganese production to the economy is in the form of direct employment (13,290 employees), employee earnings (R5.2 billion), total sales (R7.1 billion) and royalties (R158 million) in 2021 (MCSA, 2021). This industry in the downstream sector also contributes financially as well as indirectly through employment to the economy.

2.6.4. Chromium

Chromium in South Africa is found in the Bushveld Complex. It occurs mainly in the critical zone of the Bushveld Complex and found in the lower (LG), middle (MG) and upper (UG) groups (Wilson et al., 1998). Chromite is the only commercial source of chromium. It was first noticed in 1865 by Carl Mauch at the outcrop in Hex River near Rustenburg (Wilson et al., 1998). The mining of chromite started around 1916 on Goudmyn farm and in 1917 on Mooihoek farm. Production started in the Eastern Bushveld Complex and South Africa became a major producer in the chromium industry only in the 1960s (Wilson et al., 1998).

2.6.4.1. Applications and uses of chromium

Chromium has mainly been used in the metallurgical, chemical and refractories industries. The consumption of chromium is divided into categories according to the composition of their grades, namely ferrochrome, chemical, refractory and foundry. Chromium can be used in different applications, where each application has chemical constraints and specifications, such as superalloys (jet engines) and stainless steel (see Table 2.18) (DMRE, 2016).

Table 2.18: Applications and uses of chromium in different sectors

Mineral commodity	Chromium
Aerospace (non-defence)	*Jet engines (superalloys)
Defence	*Superalloys *Speciality steel
Energy	*Land-based turbines *SOFC applications
Telecommunications and electronics	N/A
Transportation (non-aerospace)	N/A
Other	*Speciality steel *Stainless steel *Corrosion resistance

Source: DMRE (2016)

2.6.4.2. Resources and reserves

Chromium resources found in South Africa are estimated at 70% of the world resources. South Africa is ranked number one and the largest producer of chromium in the world (see Table 2.7) (DMRE, 2021).

2.6.4.3. Production and supply

Chrome production in 2018 was 18 million tonnes (see Figure 2.17), which has decreased by 18.7% compared to the previous year. The total sales were R22.1 billion and the value of percentage exported is 47.1% (MCSA, 2018). The total production shows an increase of 27% in 2021 (Table 2.19) (MCSA, 2021).

The production and supply are affected by some challenges in the industry such as high operational costs due to electricity and labour including lack of utilisation of smelting facilities in the country.

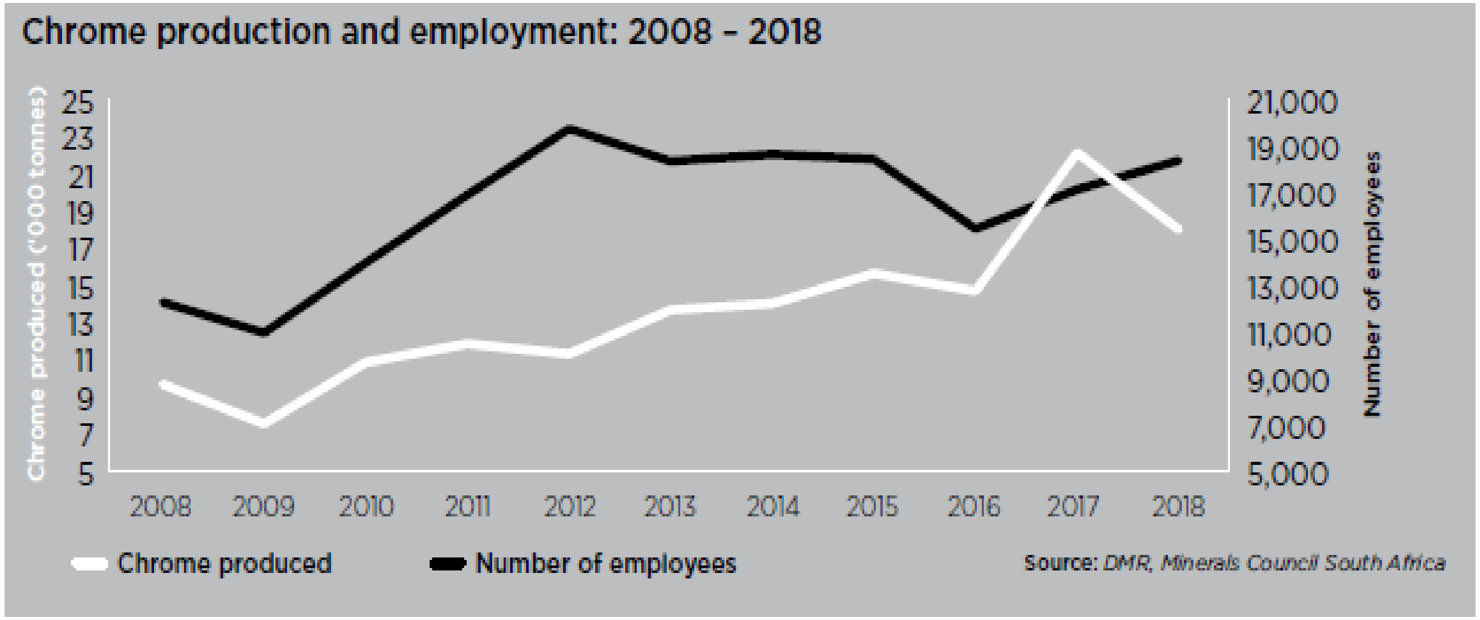


Figure 2.16: Total chrome produced and people employed between 2008 and 2018.

Table 2.19: Total Chrome ore production and sales between 2010 and 2021

Production		Local sales		Export sales		Total sales	
Year	**Tonnes**	**Tonnes**	**R'000**	**Tonnes**	**R'000**	**Tonnes**	**R'000**
2010	10,871	7,267	4,159,308	1,929	2,459,473	9,196	6,618,781
2011	11,865	7,202	5,227,339	2,152	3,649,136	9,354	8,876,475
2012	11,317	6,683	4,681,855	2,470	3,594,282	9,152	8,276,137
2013	13,690	8,483	5,870,717	4,168	5,891,833	12,651	11,762,549
2014	14,038	10,048	7,771,424	3,695	5,834,876	13,743	13,606,301
2015	15,656	9,833	8,093,409	4,821	8,104,128	14,654	16,197,537
2016	14,708	8,726	8,164,638	4,684	9,541,381	13,410	17,706,019
2017	16,671	9,060	11,027,040	4,539	12,396,254	13,600	23,423,293
2018	17,850	9,955	11,755,253	4,065	10,045,204	14,020	21,800,457
2019	17,656	10,302	11,854,069	5,245	10,453,314	15,547	22,307,382
2020	14,513	8,928	10,172,822	4,647	8,731,865	13,575	18,904,688
2021	**18,435**	**10,197**	**11,230,705**	**5,235**	**10,743,835**	**15,432**	**21,974,540**

2.6.4.4. Contribution

The contribution of chrome to the economy is in direct employment (18,397 employees), employee earnings (R5.2 billion) in 2018 (MCSA, 2018). In 2021, there was increase contribution of in direct employment (18,599 employees) and employee earnings of R6,117 billion (Table 2.20).

Table 2.20: Employment and earnings in the Chrome ore sector between 2011 and 2021

Year	Employment	Earnings (R'000)
2011	16,911	2,755
2012	19,762	3,434
2013	18,358	3,841
2014	18,658	4,047
2015	18,450	4,417
2016	15,449	4,214
2017	16,968	4,734
2018	18,935	5,518
2019	20,901	6,383
2020	19,274	6,312
2021	**18,599**	**6,117**

Source: MCSA (2021)

2.6.5. Vanadium and titanium

Vanadium is the thirteenth most common metallic element (Wilson et al., 1998). Its ore is mainly found in sedimentary and magmatic deposits. The main commercial component is iron and titanium. Most of South Africa’s vanadium is found in the Bushveld Complex within the upper zone in the titaniferous magnetites (Wilson et al., 1998). Production in South Africa started in 1957 by Minerals Engineering of South Africa Ltd Company in Emalahleni, which was taken over by Anglo American Corporation Ltd (renamed Vanadium Transvaal) in 1959 (Wilson et al., 1998). This operation and mining of vanadium extended to Kennedy’s Vale in Steelpoort where iron and steel were produced.

Highveld Steel and Vanadium Corporation Ltd were also established with steel and vanadium plants in Witbank. Other companies such as Otavi Mining, Transvaal Alloys, and Vametco were established which continued to produce vanadium from the Bushveld Complex (Wilson et al., 1998).

Titanium is the ninth most abundant element in the earth's crust and is present in minerals in the form of oxides, titanites or silicates. It is consumed in the manufacture of titanium dioxide.

The titanium oxide was discovered in the 1790's while analysing ilmenite from the coastal black sands of Cornwall (Wilson et al., 1998). It was named after the titans according to the Greek mythology. The economic production of titanium started in 1948. In South Africa, titanium was explored and exploited in the 1960's. The deposits of this mineral are derived from placer sand deposits, pegmatites and magnetites (Wilson et al., 1998).

Titanium is mostly found in five provinces, namely KwaZulu-Natal, Northern Cape, Eastern Cape, Limpopo, and Mpumalanga. Small deposits in the Free State and North-West provinces could be found (Anhausser et al., 1998).

Applications and uses: Vanadium can be used in different applications such as superalloys (jet engines) and airframes (titanium alloys) and high-strength steel (see Table 2.21). The vanadium that is mostly used in the industry is in the form of vanadium pentoxide (V_2O_5). It is critical in the development of a new energy economy. Vanadium batteries tend to be used for grid energy storage and are attached to power plants and electrical grids. Vanadium is produced by blending milled ore, slag or concentrates with sodium salt, followed by roasting and leaching (Goldberg et al., 1992).

Titanium dioxide is used primarily as a pigment in paints because of its whiteness, brightness and high refractive index (Wilson et al., 1998). The application is in the manufacture of paints, lacquers, enamels, plastics, paper, rubber, coated fabrics and textiles, printing ink, ceramics and cosmetics (Wilson et al., 1998). Titanium dioxide is also used as alloys in different applications and as coatings in welding rods (Anhausser, et al, 1998).

Table 2.21: Applications and uses of vanadium in different sectors

Mineral commodity	Vanadium and titanium
Aerospace (non-defence)	*Jet engines (superalloys) *Titanium alloys
Defence	*Titanium alloys *Speciality steel *Land-based turbines
Energy	*Petroleum catalysts *Grid scale batteries
Telecommunications and electronics	N/A
Transportation (non-aerospace)	N/A
Other	*Speciality steel *Chemical catalysts *Titanium alloys

2.6.6. Iron

Iron is one of the most abundant elements in the earth's crust and was one of the first metals used by people. The ancient miners extracted the iron ore in Southern Africa from specularite and haematite host rocks at Ngwenya in Eswatini for ornamental purposes and use as pigments (Wilson et al., 1998). Early mining was also documented by European explorers in the Northern Cape province in South Africa (Wilson et al., 1998).

The earliest smelting and fabrication of iron ore was noted from a furnace site near Tzaneen in the Limpopo province and a smelting site in Broederstroom near Hartebeespoort Dam in the North-West.

The deposits are classified into banded iron formations, magmatic deposits, gossans and residual deposits, lode, vein and replacement deposits (Wilson et al., 1998). The iron ore bearing minerals are magnetite, haematite, goethite, lepidocrocite, siderite and chamosite. Iron is mostly found in several provinces such as the Northern Cape, Limpopo, North-West, Mpumalanga and Gauteng (Anhausser et al., 1998).

Applications and uses of Iron: It has attractive physical properties which include hardness, strength, malleability, ductility, durability and ease to be used as an alloy. Iron is used in different applications in three categories, namely structural, mechanical and coverings. The steel is used in the manufacture of structural components such as building frames, bridges, highways and rail structures, industrial equipment, vehicles, aircrafts and ships. Other uses may include usage as a flux and in the ceramic industry (Anhausser et al., 1998).

Iron ore contributes to the economy, local sales increased by 18% and export sales increased by 39% in 2021. Production in 2021 increased by 31% to 73 million tonnes and total sales were R120.8 billion (see Table 2.22) (MCSA, 2021).

Table 2.22: Total Iron ore production and sales between 2010 and 2021

	Production	Local sales		Export sales		Total sales	
Year	**Tonnes**	**Tonnes**	**R'000**	**Tonnes**	**R'000**	**Tonnes**	**R'000**
2010	58,709,330	10,560,910	3,270,326	47,492,581	40,148,279	58,053,491	43,418,606
2011	58,056,897	9,844,323	4,207,746	51,890,937	58,444,148	61,735,260	62,651,894
2012	67,100,474	8,392,835	4,448,978	57,109,694	48,193,830	65,502,529	52,642,808
2013	71,644,761	9,295,336	5,776,442	58,180,390	57,360,500	67,475,726	63,136,942
2014	80,741,034	9,571,453	5,741,815	61,994,607	52,944,638	71,516,060	58,686,453
2015	72,805,534	7,512,691	5,071,073	64,175,896	34,394,014	71,688,587	39,456,086
2016	66,450,089	6,160,597	3,855,830	58,392,326	39,240,118	64,552,923	43,095,948
2017	74,789,394	7,177,079	5,187,033	60,678,253	44,188,638	67,855,332	49,375,671
2018	74,272,974	8,024,968	5,732,580	61,715,193	45,529,223	69,740,161	51,261,803
2019	72,406,782	7,548,006	5,630,784	60,582,727	65,040,115	68,130,733	70,670,899
2020	55,635,308	5,885,791	3,260,059	60,177,593	83,304,860	66,063,384	86,564,919
2021	**73,090,918**	**6,811,992**	**5,101,679**	**60,814,531**	**115,680,173**	**67,626,523**	**120,781,852**

Source: MCSA (2021)

In 2021, there was contribution of in direct employment (21,427 employees) which increased by 4.7% and employee earnings of R8,6 billion (Table 2.23). This industry in the downstream sector also contributes financially and indirectly through employment to the economy.

Table 2.23: Employment and earnings in the Iron ore sector between 2011 and 2021.

Year	Employment	Earnings (R'000)
2011	22,360	6,507
2012	23,380	4,691
2013	21,127	4,848
2014	21,794	5,692
2015	20,554	6,219
2016	16,651	5,895
2017	17,510	5,826
2018	18,613	6,641
2019	19,769	7,025
2020	20,469	7,537
2021	**21,427**	**8,557**

Source: MCSA (2021)

2.6.7. Copper, cobalt, lead, nickel and zinc

The three most important areas of South Africa where copper was discovered are Phalaborwa, Okiep and Messina (Wilson et al., 1998). Copper, together with zinc, is found in the Northern Cape. Limpopo has minor quantities in different areas as a by-product. The bushveld complex produces significant quantities of copper, nickel and cobalt as by-products (Wilson et al., 1998). Copper has strength (especially when alloyed with iron, nickel, cadmium, beryllium, chromium or manganese) and superior corrosion resistance. Its most valuable properties include high electrical and thermal conductivity and its non-magnetic nature.

Applications and uses are in the motor industry, air conditioning, marine industry, agriculture, medicine, chemical industry and electronics and communications industry. Cobalt is produced as a by-product from copper, nickel, manganese and gold ores. These resources are from the Bushveld complex. It is mostly used in superalloys, special alloys, rechargeable batteries, cemented carbides and advanced ceramics (Wilson et al., 1998).

These minerals employed 17,953 employees, which is an increase of 6.7% and earnings contribution of R7,781,000 in 2021. Production in tonnes in 2021 was for cobalt (355), copper (28,307), lead (31,224), nickel (31,846), and zinc (193,786) Table 2.24).

Sales contribution for cobalt (R170,527,000), copper (R2,745,652,000), lead (R846,283,000), nickel (R9,162,970,000), and zinc (R7,084,935,000). Total sales of more than R20 billion was contributed by these minerals to the economy of the country (MCSA, 2021).

Table 2.24: Total Copper, cobalt, lead, nickel and zinc production between 2010 and 2021

Production	Cobalt	Copper	Lead	Nickel	Zinc
Year	**Tonnes**	**Tonnes**	**Tonnes**	**Tonnes**	**Tonnes**
2010	840	83,639	50,625	39,962	36,142
2011	862	89,297	54,460	43,320	36,629
2012	1,102	69,859	52,489	45,946	37,034
2013	1,294	80,821	41,848	51,208	30,145
2014	1,332	78,697	29,348	54,956	26,141
2015	1,362	77,360	34,573	56,689	29,040
2016	1,101	65,257	39,344	48,994	26,659
2017	1,064	65,523	48,150	48,437	30,778
2018	1,007	46,900	35,118	43,236	28,129
2019	1,027	52,516	42,936	43,466	125,157
2020	897	29,068	28,048	34,908	160,816
2021	**355**	**28,307**	**31,224**	**31,846**	**193,785**

2.6.8. Gold and Uranium

Gold is mainly found in the Witwatersrand basin and other quantities around the Kraaipan and Barberton belts in the country. South Africa was the dominant gold producer in the world for a long time. It has sustained and contributed to the development of the country (Wilson et al., 1998). Production is declining and there are challenges and difficulties of extraction due to depth. Gold production increased by 9.6% in 2021 compared to 2020 resulting in total production of 105,000 kg and sales increase of 18.2% to more than R102 billion (see Table 2.25). The commodity continues to contribute to the economy of the country and provide employment (93,998 employees) and employee earnings of R30.8 billion to many citizens. Employment increased by 2.7% from 2020 (MCSA, 2021).

Uranium occurs as a by-product in different areas of South Africa and is used in nuclear power station (Koeberg). Other uses and applications are nuclear weapons, production of radioactive isotopes with applications in the fields of medicine and food irradiation (Wilson et al., 1998). South Africa is ranked number six in the world and has 279,100 tonnes of uranium reserves (Table 2.6).

Table 2.25: Total Gold production and sales between 2010 and 2021

Production		**Local sales**		**Export sales**		**Total sales**	
Year	**Tonnes**	**Tonnes**	**R'000**	**Tonnes**	**R'000**	**Tonnes**	**R'000**
2010	189	7	2,055,698	177	51,037,449	184	53,093,147
2011	180	10	3,633,111	176	65,258,302	186	68,891,413
2012	155	11	4,862,748	165	71,961,757	176	76,824,504
2013	160	10	4,192,863	151	65,793,912	162	69,986,775
2014	152	9	3,450,902	136	59,898,125	145	63,349,026
2015	145	16	7,385,852	118	55,314,075	134	62,699,927
2016	142	26	15,214,101	122	73,210,641	147	88,424,741
2017	137	33	17,292,406	119	64,894,988	152	82,187,393
2018	117	66	35,201,487	64	34,482,018	130	69,683,505
2019	105	76	48,295,654	42	28,336,141	119	76,631,795
2020	96	22	17,580,144	70	68,855,730	92	86,435,874
2021	**105**	**11**	**9,155,869**	**107**	**93,053,603**	**117**	**102,209,471**

2.6.9. Diamonds

Diamonds are mainly found in the diamond pipes and other quantities in dykes and alluvial deposits located in different provinces and towns such as Gauteng (e.g., Cullinan), Free state (e.g., Hope Town), and Northern Cape (e.g., Kimberly), and North-West (e.g., Lichtenburg) amongst others (Wilson et al., 1998). Production increased to 9,723,811 carats in 2021 and total sales increased to R21.1 billion in 2021 (Table 2.26) (MCSA, 2021).

Employment in the diamond industry was 12,900 direct employees (Table 2.27). Initiatives are implemented to explore the potential of diamonds which include favourable legislation (e.g., diamond export levy act, state diamond trader, removal of value added tax payments on imports) and conducive environment for local beneficiation of diamonds (MCSA, 2021). Diamonds continue to contribute to the economy of the country.

Table 2.26: Total Diamonds production and sales between 2010 and 2021

	Production	Local sales		Export sales		Total sales	
Year	**Carats**	**Carats**	**R'000**	**Carats**	**R'000**	**Carats**	**R'000**
2010	8,869,532	-	-	-	-	-	-
2011	7,046,277	-	-		-	-	-
2012	7,245,402	-	-	-	-	-	-
2013	8,159,531	3,425,339	7,552,445	3,768,082	4,792,191	7,193,421	12,344,635
2014	8,095,037	3,168,609	8,800,678	5,619,831	7,730,529	8,788,440	16,531,206
2015	8,229,657	3,138,546	8,613,267	4,650,483	5,811,860	7,789,029	14,425,128
2016	8,302,110	1,609,160	8,325,338	9,002,389	12,435,825	10,611,549	20,761,163
2017	9,678,752	1,015,882	7,912,460	9,118,652	10,230,438	10,134,534	18,142,898
2018	9,914,612	1,427,590	7,186,242	8,869,716	10,074,788	10,297,306	17,261,029
2019	7,176,996	945,737	5,499,937	6,273,530	7,664,806	7,219,267	13,164,743
2020	8,471,642	1,284,873	5,151,826	5,901,679	8,119,626	7,186,552	13,271,453
2021	**9,723,811**	**2,073,975**	**7,928,797**	**8,283,288**	**13,210,210**	**10,357,263**	**21,139,007**

Source: MCSA (2021)

Table 2.27: Employment and earnings in the diamond sector between 2011 and 2021

Year	Employment	Earnings (R'000)
2011	12,047	2,141
2012	12,332	2,408
2013	13,579	2,871
2014	15,356	3,663
2015	18,313	4,678
2016	18,789	5,073
2017	18,038	5,430
2018	16,361	5,198
2019	15,252	4,945
2020	13,939	4,505
2021	**12,900**	**4,880**

Source: MCSA (2021)

2.6.10. Lithium

Minor deposits can be found in the Northern Cape, KwaZulu-Natal and Gauteng (Wilson et al., 1998). However, lithium is in competition with other deposits within Africa and globally, which may be more attractive to investment for different reasons, such as grade, size, access and related permitting requirements. The applications of lithium are mostly found in rechargeable batteries (see Table 2.28) (DMRE, 2016).

Table 2.28: Applications and uses of lithium in different sectors

Mineral commodity	Lithium
Aerospace (non-defence)	*Rechargeable batteries *Aluminium alloys (structural)
Defence	**Rechargeable batteries *Aerospace alloys *Tritium production support
Energy	*Rechargeable batteries *Cooling water chemistry in nuclear power reactors
Telecommunications and electronics	*Rechargeable batteries
Transportation (non-aerospace)	*Rechargeable batteries

Other	*Glass and ceramics manufacturing *Lubricant *Medical applications

2.6.11. Rare earth elements (REE)

The REE market is dominated by China with most reserves and ranked number one (MCSA, 2021). REE are found in minor quantities in Steenkampskraal in the Northern Cape province (Wilson et al., 1998). These elements have many applications (see Table 2.29) (DMRE, 2016).

Table 2.29: Applications and uses of rare earth elements in different sectors

Mineral commodity	Rare Earth Elements
Aerospace (non-defence)	*Jet engines (ceramics, superalloys)
Defence	*Guidance systems *Lasers *Radar *Sonar
Energy	*Petroleum catalysts *Permanent magnets for electric motor and wind turbines *Fuel additives *Nuclear applications *Rechargeable batteries *Turbines (superalloys, coating) *SOFC applications
Telecommunications and electronics	*Fibre optics *Signal amplifiers *Cellular phones *Flat-panel displays *Hard-disk drives *Lighting *Electric motors *Sensors
Transportation (non-aerospace)	*Autocatalysts

	*Electric motor magnets *Automotive glass
Other	*Ceramics *Steel and nonferrous alloys *Chemical catalysts *Permanent magnets *Polishing compounds *Lasers *Optical glass *Medical imaging *X-ray scintillometers

Other minerals and materials mined in the country include silver, cobalt, lead concentrate, nickel, uranium, aggregate and sand, feldspar, granite, gypsum, limestone and lime, salt, shales for cement manufacture, silica and sulphur. The production quantities of these minerals and materials for a period of ten years indicate that their contribution to the economy and mining sector cannot be ignored (see Table 2.30) (DMRE, 2018). Employment in these other minerals sector was 4,998 employees in 2021 (MCSA,2021).

Table 2.30: Commodity and South African production compared from 2008 to 2018

OTHER MINERALS

Production: 2008 - 2018

	Silver (t)	Cobalt ('000kg)	Lead concentrate (t)	Nickel (t)	Uranium ('000kg)	Aggregate and sand (kt)	Feldspar (kt)
2008	75	244	46	32	654	58,608	106
2009	78	238	49	35	629	53,604	101
2010	79	840	51	40	682	52,625	94
2011	73	862	54	43	656	51,595	102
2012	67	1,102	52	46	551	54,649	94
2013	69	1,294	42	51	626	60,375	191
2014	49	1,332	29	55	668	62,192	103
2015	52	1,362	35	57	528	63,779	130
2016	56	1,101	39	49	450	64,478	128
2017	63	1,062	48	48	304	67,394	116
2018	49	940	33	41	240	59,706	74

	Granite (kt)	Gypsum (kt)	Limestone and lime (kt)	Salt (kt)	Shales for cement manufacture (kt)	Silica (kt)	Sulphur (kt)
2008	544	571	23,495	430	418	3,342	571
2009	396	598	22,698	408	462	2,306	536
2010	346	513	22,480	394	388	2,863	375
2011	332	476	21,630	380	401	2,688	338
2012	271	558	21,637	399	423	2,155	257
2013	331	559	21,966	477	468	2,296	270
2014	233	376	21,776	494	402	2,605	277
2015	263	232	22,927	517	333	2,278	284
2016	253	257	23,358	488	380	1,884	281
2017	282	318	24,715	507	359	2,448	257
2018	281	355	22,399	458	301	2,209	232

Source: MCSA (2010)

2.7. South African minerals and their economic contribution to the economy

The economic contribution of the mining sector is important to the country. The economic contributions include employment (i.e., jobs), GDP (Gross Domestic Product), foreign exchange, investment, foreign savings, corporate tax, royalties, operational and capital expenditures, wages and salaries, Transnet's rail and port, electricity generation, electricity demand (consumption), and liquid fuels.

The mentioned aspects of contribution in South Africa can be observed over a decade (i.e., 2001 – 2010), where the contributions from the mining industry to the different sectors of the economy have been significant (see Table 2.31).

Table 2.31: The contribution of the mining sector in South Africa over a 10-year period – key mineral industry statistics for South Africa

Description	Units of measure	2001	2005	2010	10 yr total / average
GROSS DOMESTIC PRODUCT					
Direct contribution of mining to GDP	R'millions nominal terms	77 214	105 992	230 402	1 372 138
Direct contribution of mining to GDP	R'millions constant 2005 prices	99 019	105 992	100 659	1 019 183
Direct contribution of mining to GDP	R'millions 2010 money terms	131 674	148 346	230 402	1 716 067
Mining GDP growth rate	% YoY	0.1	1	-4.5	-1.4
Direct contribution of mining to GDP	US$ equivalent	8 975	16 661	31 466	181 093
South African GDP	R'millions nominal terms	1 020 007	1 571 082	2 664 269	17 567 950
South African GDP	R'millions constant 2005 prices	1 337 382	1 571 082	1 834 435	16 057 357
Mining's contribution as % of total GDP nominal terms	%	7.6	6.7	8.6	7.8
Mining's contribution as % of total GDP real terms	%	7.4	6.7	5.5	6.3
FIXED TERM INVESTMENT					
Direct contribution of mining to fixed investment (GFCF)	R'millions nominal terms	15 871	16 743	63 298	346 843
Direct contribution of mining to fixed investment (GFCF)	R'millions constant 2005 prices	19 684	16 743	42 569	287 737
Direct contribution of mining to fixed investment (GFCF)	R'millions 2010 money terms	27 065	23 433	63 298	422 654
Total private sector fixed investment (private GFCF)	R'millions nominal terms	113 039	196 267	317 136	2 248 769
FIXED TERM INVESTMENT					
Total SA fixed investment (GFCF)	R'millions nominal terms	151 008	263 754	521 613	3 318 680
Mining fixed investment growth rate	% YoY	8	-12	-5	11
Direct contribution to fixed investment (GTCT)	US$ equivalent	1 845	2 632	8 645	42 250
Mining's contribution to private sector fixed investment (GFCF)	%	14	8.5	20	15.4
Mining's contribution as % of total investment	%	10.5	6.3	2.1	10.5
SALES AND EXPORTS					
Total primary mineral sales	R'millions nominal terms	115 853	143 448	280 124	1 984 605
Total primary mineral sales	US$ equivalent	13 466	22 548	51 914	261 984
Total primary mineral sales	R'millions 2010 money terms	197 567	200 769	380 124	2 477 930
Mining industry primary exports	R'millions nominal	90 833	102 487	302 175	1 480 838

Description	Units of measure	2001	2005	2010	10 yr total / average
	terms				
Mining industry primary exports	US$ equivalent	10 558	16 110	41 268	195 044
Mining industry primary exports	R'millions 2010 money terms	154 899	143 440	302 175	1 847 005
Total SA merchandise exports	R'millions nominal terms	265 832	358 361	625 359	4 430 693
Total SA exports (goods and services)	R'millions nominal terms	328 428	459 719	761 320	5 533 098
Primary mineral exports as % of total SA merchandise exports	%	34.2	28.6	28.3	33.4
Primary mineral exports as % of total SA exports	%	27.7	22.3	39.7	26.8
Mining export earnings per unit of GDP created	ratio	1.2	1	1.3	1.1
EMPLOYMENT					
Mining industry direct employment	numbers	406 994	444 132	498 141	4 611 802
Total private non-agricultural employment	numbers	3 075 838	5 506 592	6 235 318	54 582 888
Total SA formal non-agricultural employment	numbers	4 658 417	7 110 705	8 156 954	71 481 052
Mining as % of total private non-agricultural employment	%	13.2	8.1	8	8.4
Mining as % of total non-agricultural formal employment	%	8.70	6.2	6.1	6.5
Remuneration paid to employees in mining	R' millions current	24 369	36 683	74 226	442 488
Remuneration paid to employees in mining	R' millions 2010 money terms	41 556	51 341	74 226	553 752
Average annual remuneration per mineworker	Rand	59 874	82 595	149 006	939 600
EXCHANGE RATES					
Rand per US$ exchange rate	R/US$	8.60	6.36	7.32	7.73
Rand per Euro	R/Euro	7.70	7.91	9.71	9.37
Rand real effective exchange rate	Rand index	91.39	112.5	113.89	102.31
COMMODITY PRICES					
Gold price	Rand per kg	75 174	90 822	286 402	1 508 142
Gold price	US$/oz	271	445	1 225	617
Platinum price	Rand per kg	146 325	183 488	379 170	252 437
Platinum price	US$/oz	529	897	1 611	1 034
Palladium price	Rand per kg	166 857	41 211	123 926	85 758
Palladium price	US$/oz	603	201	526	339
Rhodium price	Rand per kg	443 630	420 597	578 594	662 619
Rhodium price	US$/oz	1 604	2 056	2 458	2 737
PGM production weighted average basket price	Rand per 3E kg produced	173 093	156 896	311 770	231 289
PGM production weighted average basket price	Rand/3E kg 2010 real money terms	295 178	219 591	311 770	2 933 620
PGM production weighted average basket price	US$ per 3E oz produced	625.80	767.02	1324.36	945.52

Description	Units of measure	2001	2005	2010	10 yr total / average
Coal price - average for local sales (received price)	R/ton (FOR)	63	86	194	111
Coal price - average for export sales (received price)	R/ton (FOB)	246	296	553	369

Source: MCSA (2010)

South African minerals are important for national security and the economy in the GDP contribution and employment amongst others. The mining industry contributed approximately 8.7% to the GDP in 2021.

In more detail, the contribution to the economy was as follows: R480.9 billion to GDP; total primary sales of R849.6 billion; mineral export sales of R841.6 billion; royalties paid to the value of R27.9 billion; company taxes paid to the value of R78 billion; employee taxes paid to the value of R27 billion; employee earnings of R153.8 billion and employment of 458,954 employees (see Table 2.32) (MCSA, 2021). This clearly shows the significant contribution of the mining industry to the economy of the country and the citizens.

Table 2.32: The contribution of the mining sector in South Africa over a 10-year period – key mineral industry statistics for South Africa.

Description	Units of measure	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Year-on-year % change
Gross domestic product													
Direct contribution of mining to GDP (value add)	R'millions nominal terms	216,442	218,985	238,283	239,209	227,875	251,631	268,306	287,199	315,116	353,222	480,992	36.2%
Direct contribution of mining to GDP	R'millions constant 2015 prices	217,357	209,214	217,469	213,854	223,745	220,141	225,420	223,666	221,217	194,968	217,996	(1.1%)
Mining GDP growth rate	% YoY	(0.6)	(3.7)	3.9	(1.7)	4.6	(1.6)	2.4	(0.8)	(1.1)	(11.9)	11.8	
Direct contribution of mining to GDP	US$ equivalent	29,841	26,673	24,692	22,058	17,872	17,108	20,154	21,702	21,810	21,459	32,543	0.5%
South African GDP (value added at basic prices)	R'millions nominal terms	3,035,118	3,236,488	3,502,361	3,738,791	3,981,758	4,288,841	4,592,450	4,820,365	5,039,287	4,997,872	5,563,477	4.5%
South African GDP (value added at basic prices)	R'millions constant 2015 prices	3,698,088	3,782,074	3,876,980	3,936,505	3,981,758	4,014,646	4,061,243	4,121,231	4,124,458	3,879,360	4,063,693	0.1%
Mining's contribution as % of total GDP nominal terms	%	7.1%	6.8%	6.8%	6.4%	5.7%	5.9%	5.8%	6.0%	6.3%	7.1%	8.6%	
Mining's contribution as % of total GDP real terms	%	5.9%	5.5%	5.6%	5.4%	5.6%	5.5%	5.6%	5.4%	5.4%	5.0%	5.4%	
Fixed investment													
Direct contribution of mining to fixed investment – gross fixed capital formation (GFCF)	R'millions nominal terms	71,633.8	75,235.3	91,823.1	93,868.5	70,285.5	59,424.7	76,021.8	97,139.1	101,655.9	92,018.5	114,409.9	4.6%
Direct contribution of mining to fixed investment (GFCF)	R'millions constant 2015 prices	94,131	92,427	103,276	98,076	70,285	54,855	70,261	86,494	86,514	74,614	75,878	0.0%
Total private sector fixed investment (private GFCF)	R'millions nominal terms	375,458	414,515	461,274	490,222	502,967	535,114	554,431	590,968	620,719	540,674	581,515	5.0%
Total South African fixed investment (GFCF)	R'millions nominal terms	578,014	625,643	721,234	775,950	822,576	846,552	873,223	886,428	908,878	757,318	809,899	2.5%
Mining fixed investment growth rate	% YoY	(3.1%)	(1.8%)	11.7%	(5.0%)	(28.3%)	(22.0%)	28.1%	23.1%	0.0%	(13.8%)	1.7%	
Direct contribution to fixed investment (GFCF)	US$ equivalent	9,876.4	9,163.9	9,515.1	8,655.9	5,512.3	4,040.1	5,710.4	7,340.2	7,035.8	5,590.4	7,740.9	38.5%
Mining's contribution to private sector fixed investment (GFCF)	%	19%	18%	20%	19%	14%	11%	14%	16%	16%	17%	20%	
Minings contribution as % of total investment	%	12%	12%	13%	12%	9%	7%	9%	11%	11%	12%	14%	

Continued - Table 2.32: The contribution of the mining sector in South Africa over a 10-year period – key mineral industry statistics for South Africa.

Description	Units of measure	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Year-on-year % change
Sales and exports													
Total primary mineral sales	R'millions nominal terms	370,832.7	363,756.5	385,033.1	386,350.0	386,709.4	424,041.9	474,170.8	498,289.4	552,365.1	607,547.4	849,633.7	10.9%
Total primary mineral sales	US$ equivalent	51,127.7	44,306.9	39,898.9	35,626.7	30,328.6	28,829.2	35,617.4	37,652.4	38,230.1	36,910.5	57,485.4	1.5%
Mining industry primary exports	R'millions nominal terms	282,296.6	202,331.5	234,881.4	236,205.7	211,492.5	226,776.6	296,828.8	296,745.1	321,793.7	329,450.0	438,534.2	33.1%
Mining industry primary exports	US$ equivalent	38,921.0	24,644.7	24,339.5	21,781.4	16,586.8	15,417.8	22,296.3	22,423.0	22,271.9	20,015.2	29,670.8	48.2%
Total South African exports (merchandise)	R'millions nominal terms	782,663.9	812,402.2	919,811.0	1,005,739.4	1,027,655.7	1,115,945.6	1,183,542.4	1,249,348.0	1,295,144.6	1,394,959.4	1,820,394.6	30.5%
Primary mineral exports as % of total South African exports	%	36.1%	24.9%	25.5%	23.5%	20.6%	20.3%	25.1%	23.8%	24.8%	23.6%	24.1%	2.0%
Employment													
Mining industry direct employment	numbers	512,874	524,869	509,909	492,931	480,205	458,291	463,901	456,438	460,015	453,585	461,656	1.8%
Total South African formal non-agricultural employment	numbers	8,656,951	8,906,362	9,064,960	9,258,630	9,399,279	9,711,074	9,853,734	10,107,030	10,220,218	9,729,156	9,613,540	(1.2%)
Mining as % of total non-agricultural formal employment	%	5.9%	5.9%	5.6%	5.3%	5.1%	4.7%	4.7%	4.5%	4.5%	4.7%	4.8%	3.0%
Remuneration paid to employees in mining	R'millions current	86,972	93,630	100,753	102,146	114,085	120,515	128,558	134,454	143,539	149,642		(100.0%)
Average annual remuneration per mineworker	Rand	169,578	178,388	197,590	207,223	237,576	262,966	277,123	294,572	312,033	329,909	0	(100.0%)
Exchange rates													
Rand per US$	R/US$	7.3	8.2	9.7	10.8	12.8	14.7	13.3	13.2	14.4	16.5	14.8	(10.2%)
Rand per Euro	R/Euro	10.1	10.6	12.8	14.4	14.1	16.3	15.0	15.4	16.2	18.8	17.5	(6.9%)
Rands per British Pound (GBP)	R/GBP	11.6	13.0	15.1	17.9	19.5	20.0	17.2	17.6	18.4	21.1	20.3	(3.7%)

Source: MCSA (2021)

The South African GDP growth rate declined by 2.87% from 2021 to 2022 (see Table 2.33). Mining's contribution as the percentage of total GDP in real terms was 5.4% in 2021 (See Table 2.3) (MCSA, 2021).

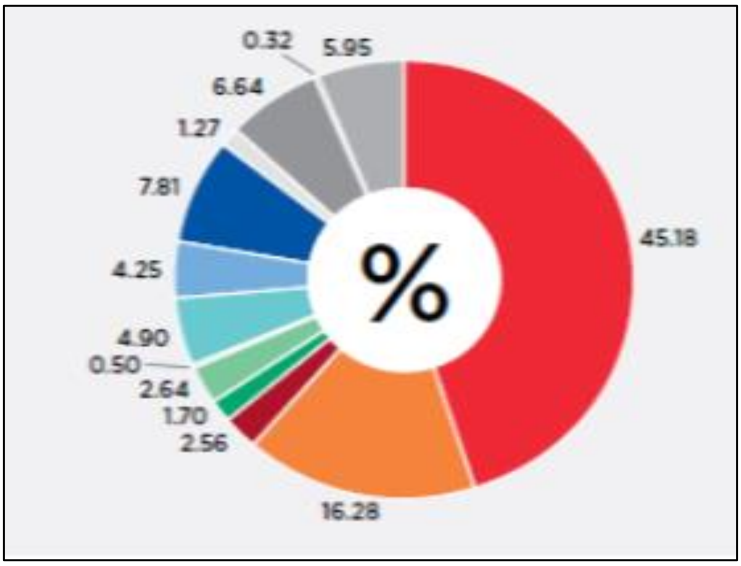
Table 2.33: South African GDP Growth Rate between 2022 and 2011

South Africa GDP Growth Rate - Historical Data		
Year	**GDP Growth (%)**	**Annual Change**
2022	2.04%	-2.87%
2021	4.91%	11.26%
2020	-6.34%	-6.65%
2019	0.30%	-1.22%
2018	1.52%	0.36%
2017	1.16%	0.49%
2016	0.66%	-0.66%
2015	1.32%	-0.09%
2014	1.41%	-1.07%
2013	2.49%	0.09%
2012	2.40%	-0.77%
2011	3.17%	0.13%

Mining industry in the downstream contributes directly and indirectly in the form of expenditures. The biggest two mining sector expenditures are in purchases (45.18%) and employment costs (16.28%) (see Table 2.34) (MCSA, 2021).

Table 2.34: Mining sector expenditure in 2021

Expenditure Item	R million	%
Purchases	451,907	45.18%
Employment costs	162,840	16.28%
Interest paid	25,645	2.56%
Royalties paid	17,014	1.70%
Paid rental on land and buildings	26,426	2.64%
Paid rental on plant and machinery	5,051	0.50%
Depreciation	48,966	4.90%
Losses on assets	42,502	4.25%
Tax and company tax	78,093	7.81%
Buildings, improvements and construction works	12,727	1.27%
Expenditure on plant, machinery, furniture, fittings and other equipment	66,389	6.64%
Capital expenditure: capital expenditure on vehicles	3,228	0.32%
Other expenditure	59,509	5.95%
Total expenditure	**1,000,297**	**100%**



This industry in the downstream sector also contributes financially and indirectly through employment to the economy. The top three commodities in 2021 that employed more people in the industry are PGM's (171,568), gold (93,998) and coal (92,670) respectively. Other commodities employing more than 15,000 employees are Iron ore (21,247), chrome ore (18,599) and non-ferrous metals (17,953) followed by commodities employing more than 10,000 employees such as manganese (13,290), diamonds (12,900) and industrial minerals (11,551) (see Table 2.35) (MCSA, 2021).

Table 2.35: Employment per commodity

	Total	Gold	PGMs	Diamonds	Chrome ore	Iron ore	Manganese	Non-ferrous metals	Coal	Industrial minerals	Other minerals
2011	512,874	144,799	194,745	12,047	16,911	22,360	7,460	-	78,580	13,013	22,961
2012	524,869	142,200	197,752	12,332	19,762	23,380	8,685	-	83,244	13,795	23,719
2013	509,909	131,738	191,260	13,579	18,358	21,127	9,842	15,539	88,039	13,623	6,805
2014	492,931	119,007	186,864	15,356	18,658	21,794	9,971	15,816	86,106	13,031	6,330
2015	480,205	115,029	186,465	18,313	18,450	20,554	8,639	16,414	77,747	12,866	5,727
2016	458,291	116,572	172,556	18,789	15,449	16,651	7,242	14,754	77,259	13,222	5,797
2017	463,901	112,901	172,760	18,038	16,968	17,510	7,780	16,325	82,372	13,029	6,219
2018	456,438	100,189	167,041	16,361	18,935	18,613	9,352	17,466	89,647	12,712	6,121
2019	460,015	92,916	168,102	15,252	20,901	19,769	11,143	19,593	94,297	12,195	5,847
2020	452,866	91,649	164,703	13,939	19,274	20,469	12,198	19,246	91,649	11,530	5,237
2021	**458,954**	**93,998**	**171,568**	**12,900**	**18,599**	**21,427**	**13,290**	**17,953**	**92,670**	**11,551**	**4,998**

Source: MCSA (2021)

Employee earnings forms part of the indirect contribution of the mining industry to the community. The employee costs have been increasing from 2011 at R86.9 billion to R166.2 billion in 2021. The top three commodities with higher employee earnings are PGM's (R67.3bn), coal (R31.4bn) and gold (R30.8bn) (see Table 2.36) (MCSA, 2021).

Table 2.36: Employee earnings per commodity

	Total	Gold	PGMs	Diamonds	Chrome ore	Iron ore	Manganese	Non-ferrous metals	Coal	Industrial minerals	Other minerals
2011	86,972	20,841	30,482	2,141	2,755	6,507	1,278	-	16,069	1,402	5,499
2012	93,630	22,238	34,393	2,408	3,434	4,691	1,565	-	17,446	1,598	5,857
2013	100,753	23,930	37,710	2,871	3,841	4,848	1,947	3,590	18,949	1,680	1,387
2014	102,146	23,383	35,652	3,663	4,047	5,692	2,302	3,691	20,595	1,810	1,311
2015	114,085	24,578	44,955	4,678	4,417	6,219	2,199	3,947	19,932	1,924	1,235
2016	120,515	28,761	45,926	5,073	4,214	5,895	2,118	4,042	21,112	2,074	1,301
2017	128,558	30,168	49,484	5,430	4,734	5,826	2,391	4,440	22,442	2,129	-
2018	134,454	27,677	51,412	5,198	5,518	6,641	3,002	5,289	25,924	2,201	1,592
2019	143,539	25,859	55,976	4,945	6,383	7,025	3,861	6,601	28,991	2,208	1,691
2020	151,753	26,904	61,083	4,505	6,312	7,537	4,430	6,746	30,516	2,062	1,655
2021	**166,155**	**30,806**	**67,312**	**4,880**	**6,117**	**8,557**	**5,197**	**7,781**	**31,401**	**2,353**	**1,751**

Source: MCSA (2021)

The number of female employees in the mining industry is growing from 2011 to 2021. In 2011, there were 44,283 female employees which increased to 65,490 employees in 2021 (see Table 2.37) (MCSA, 2021).

Table 2.37: Mining employment by gender

	Male		Female		Total
	Number	%	Number	%	Number
2011	468,591	91	44,283	9	512,874
2012	476,469	91	48,399	9	524,869
2013	459,750	90	50,159	10	509,909
2014	440,547	89	52,384	11	492,931
2015	426,332	89	53,873	11	480,205
2016	404,664	88	53,627	12	458,291
2017	407,320	88	56,581	12	463,901
2018	398,583	87	57,855	13	456,438
2019	400,324	87	59,691	13	460,015
2020	386,009	86	62,315	14	448,324
2021	**393,464**	**86**	**65,490**	**14**	**458,954**

Source: MCSA (2021)

South Africa was chosen by the U.S. as an important country to supply strategic and critical minerals and materials (Van Rensburg and Pretorius, 1977). In 1975, twenty minerals were regarded as minerals of strategic importance from South Africa; namely, gold, coal, platinum group metals, diamonds, copper, manganese, asbestos, nickel, uranium oxide, iron, chrome, vanadium, phosphate rock, antimony, zinc, tin, silver, fluorspar, vermiculite and lead (Van Rensburg and Pretorius, 1977). These minerals listed above from gold to lead in their order of importance as contributors to income from sales were responsible for 96% of the total sales.

Platinum, manganese and chromium posed a concern to the Western countries in the 1990's because of their important military and essential civilian uses (Kessel, 1990).

In the 1990s, the United States depended mostly on imports of essential minerals used in the production of strategic items such as military jet engines, avionics, ships and tanks, artillery, and space vehicles. The Republic of South Africa was identified by the US as the richest source of strategic minerals in the world that deserved special attention. It possesses the one of the old Archaean rock rich in gold, iron and manganese. South Africa contains 85% of the world's proven reserves of chromium, 70% of manganese, 90% of platinum group metals, and 50% of vanadium (Kessel, 1990).

A country tends to depend on other countries for supply of minerals. This may lead to mineral dependency, which makes the country vulnerable (Anderson, 1993). No country in the world is totally self-sufficient when it comes to mineral supply. Strategic minerals can be seen as domestic insufficiency of minerals. It is important to keep the balance between mineral imports and exports.

The position of the country with regard to mineral dependency or vulnerability is affected by the following factors: rising nationalism, nationalisation, expropriation, increased taxation, constraints in foreign ownership, higher energy costs and restrictive environmental regulations (Achzet and Helbig, 2013). In addition, mineral status is crucial in terms of the country of origin, richer mineralised ore deposits, location close to cheaper energy sources, distance to the market, low-cost labour and industrial demand.

The industrial demand in mineral-rich countries is mostly lower than the available supplies which result in those countries becoming exporters of minerals. The benefits of import for the US in 1990 was that the nation and its citizens gained economic advantages – lower costs and higher real incomes, explained as the economic public good well-served (Kessel, 1990).

The US followed a few steps to reduce import dependence; namely expanding domestic production, diversifying sources of supply, recycling, finding substitutes or developing synthetics, increasing dependence of supplying countries upon continuing US goodwill, and allocating supplies through a priority use system (Haglund, 1984).

In terms of the contributions of the total mining value-add (production) of the minerals, the four major contributors in South Africa are coal (24%), platinum group metals (23%), gold (16%) and iron ore (12%) (MCSA, 2018). Other minerals contribute about 24% towards the total percentage (see Figure 2.18). The mining industry is experiencing challenges, as the total mining production fell by 1.6% in 2018 compared to 2017 (StatsSA, 2019).

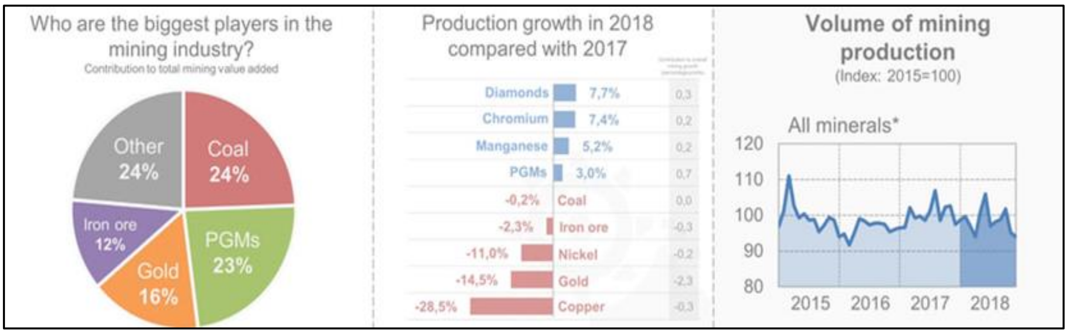


Figure 2.17: Mining contribution of different minerals in 2018

The mining industry contributed approximately 6.8% and 7.3% to the GDP in 2017 and 2018 respectively. In more detail, the contribution to the economy was as follows: R356bn to GDP; direct contribution to fixed investment of R93bn; total primary sales of R475bn; mineral export sales of R312bn; royalties paid to the value of R7.6bn; company taxes paid to the value of R22bn; employee taxes paid to the value of R21bn; and employment of approximately 453,543 employees (MCSA, 2019).

2.8. Socio-economic impacts of mining

2.8.1. Introduction

Mining activities are risky for the employees and communities. Mining is mostly seen as a sector that can contribute to the economic growth of the country and reduce poverty through employment (StatsSA, 2018). Mining companies are in the business of extracting valuable resources for profit, where technical, legal and commercial functions which support production mining are understood as the core of the business (Kemp and Owen, 2013).

Corporate social responsibility is based on issues such as social interests, environmental protection, and relationships with local community groups in the company's strategy by focusing on building the right relationships with employees. It has become important due to the character of activities associated with mining. It is also not well understood, as companies compare it with philanthropy where their actions are limited to primarily making token charity donations (Kabir and Petersen, 2015).

Mining activities have negative and positive impacts on local communities, and four factors can be used to determine the impact. The factors are employment opportunities, environmental pollution, land expropriation, land subsidence and settlement (Yang and Ho, 2019).

The government has adopted different policy legislations to address and minimise the socio-economic impacts of mining activities in different local communities (e.g., Mining Charter III, National Environmental Management Act). This is regulated through several departments such as the DWAF, DEAF, DFFE, DMRE, etc. The government state organs require a social and labour plan (SLP), environmental authorisation (EA), and EMPR before the mining license is issued. There is also a provision for the requirements for the closure certificates. Mining companies make a commitment to honour their SLPs before they start the operations and implement mitigation plans of identified impacts on the community and environment.

2.8.2. Local economic development

Several studies (Yang and Ho, 2019; Bismark and Darkor, 2015) have been conducted on the socio-economic impacts of mining. There are positive and negative impacts on the communities as indicated in Figure 2.19. These studies have confirmed that mining can contribute towards economic growth, reduction in poverty, employment, and increase the global integration of the economy within the country and local communities (Yang et al., 2019).

It has also been found (Bismark et al., 2015) that local businesses are able to grow their business and create more indirect opportunities as result of mining. Similarly, mining can adversely affect the communities.

Positive contributions of the mining operations include local employment generation and other economic activities. The activities include industries, commercial businesses, social services and small-scale employment. The high employment generation which is available for local people is the low-class type which does not reward them that much.

The self-employed sectors are farming, retailing and artisanship. The town Selebi-Phikwe experienced a high growth of private sector investments since the establishment of the mine (Bismark et al., 2015). Infrastructure such as roads, telecommunications, rail and airstrip has improved. Other manufacturing and engineering industries, commercial businesses such as banks, restaurants, wholesale and retail shops started to develop, which serve the neighbouring villages as well.

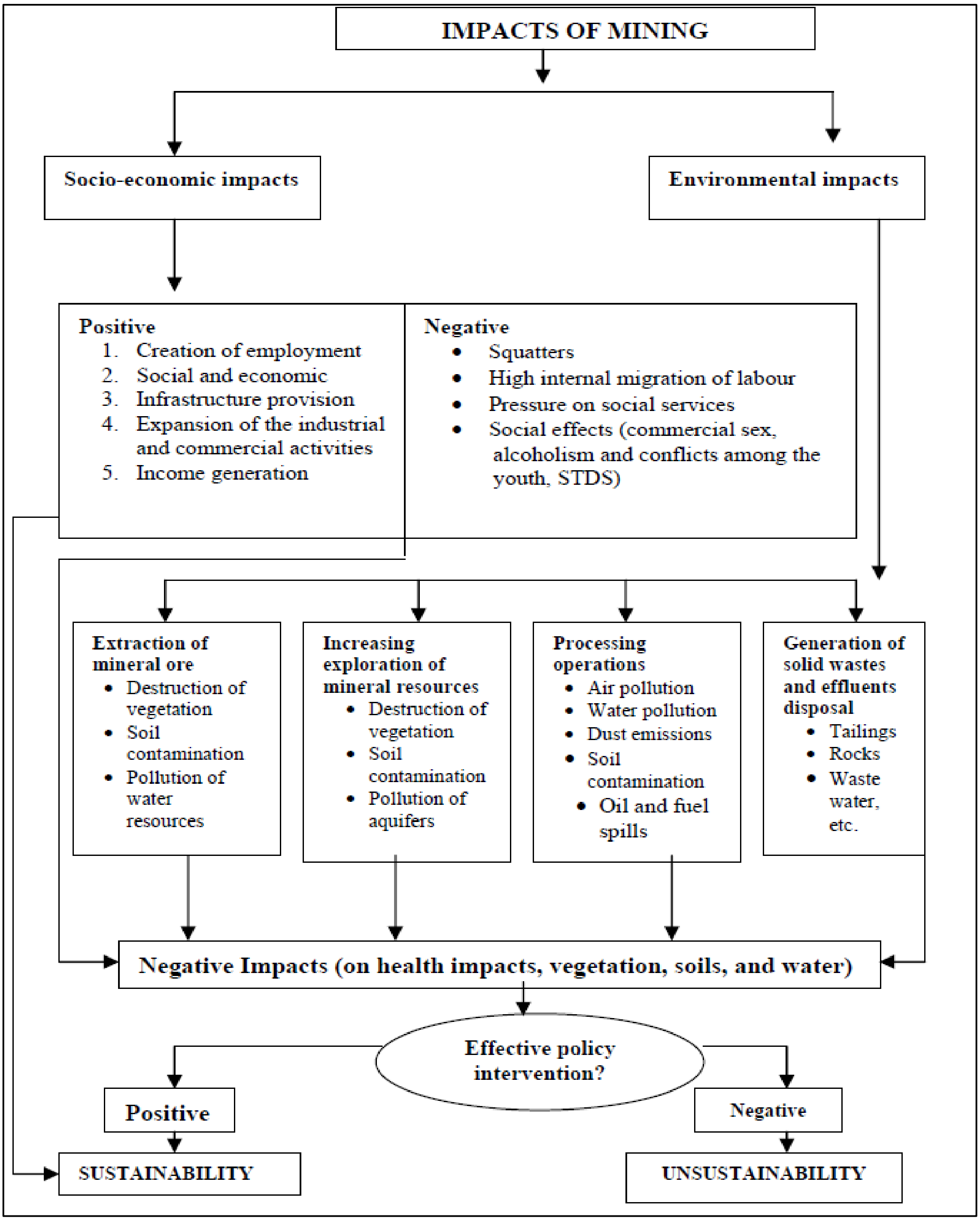


Figure 2.18: Impacts of mining

The local council should promote entrepreneurship development training programmes, a financial assistance policy, investment promotion in the community, establishment of board for small scale businesses and industries to promote development and improvement in the informal business sector where most of the unskilled labour is found.

Diversification into other productive ventures like livestock farming, poultry and arable farming, and open community skills training colleges to many of its employees is a good example from Ashanti Goldfields in Ghana (Ackerman et al., 2018).

Local mining communities benefit from the mining operations in their area; however, it can also create the inflow of migrants from different areas to the local community. According to Yang et al. (2019), the differences in the employee's income between the mining and agriculture can affect the lifestyle and living standards. The high number of migrants increases the demand of goods and services which increase production and consumption. The high demand of goods and services lead to increases in prices. Mining-related employment provides high salaries and households prefer their family members to work in the mines. The people from the community may not afford the costs of the goods and services which mine employees may afford. These issues change the standard of living and increase the cost of living in the local community.

2.8.3. Social and community impacts

The mining activities affect local communities especially in the area of land use and eco-systems. There are emissions from mining and processing such as dust, noise, wastewater, pollution, heavy metals and decreased quality of the ecosystem.

The social impacts include displacement and unemployment, child labour, accidents, theft, prostitution, increased incidents of banditry, early drop-out from school, changes to an indigenous lifestyle, and competition among local residents for natural resources. To some communities, displacements result in food insecurity, increased poverty, environmental degradation, and conflicts.

The most negative perceptions from the community were land subsidence due to mining, long processes of relocation, insufficient compensation, and long-term livelihood concerns (Yang et al., 2019). The affected farmers were only relocated upon occurrence of a visible land subsidence. In the initial relocation and resettlement, the funds are budgeted only for the communities near the key state-owned mines (Yang et al., 2019). Mining has been associated with low compensation and high conflicts. Resettlement does not improve the perceived benefits of mining compared to the unaffected farmers.

In the South African context is the Twickenham mine owned by Anglo American Platinum (Amplats) that was placed on care and maintenance in July 2016: Some people believe that life was better before the mine opened because it is harder, and life has been difficult in the villages and townships when the mines closed (Ackerman et al., 2018). The people are now used to making a living through the direct and indirect benefits of mining activities because they are no longer used to the old ways of making a living.

Communities can no longer farm as they used to because most of the boreholes are dry and land for ploughing has either been destroyed or taken up by mining operations. Economic activities have also stopped. In addition, people start to survive on social grants and others have to survive through alternative ways (Yang et al., 2019).

The high unemployment rate leads to crime and theft. Those who did not work in the mines feel that they never benefited from the mining operation in their community. They expected the mine to provide their children with bursaries and training to be able to sustain their families after the mining. They remained with their livestock and small-scale farming activities. These people are now experiencing theft of their livestock and damages to the farm due to high unemployment. The retrenched or unemployed mine workers are now part of the people. Mining activities disrupt the lifestyle and living standards including the cost of living in a community.

The Orkney and Grootvlei mines (which were owned by liquidated Pamodzi Gold Ltd) case study showed that mine closures generally leave behind polluted areas, abandoned mines and ghost towns (Ackerman et al., 2018). These closures have devastating effects on the surrounding mining communities and employees. When the mines close, mine workers do not immediately leave the sites to find alternative employment. Their whole lives are affected in terms of nutrition, health, education, food security, water, shelter, community participation, and personal safety (Ackerman et al., 2018).

In the survey of the perceptions of the rural local community in China (Yang et al., 2019), only a few people, about 20%, consider mining as beneficial to the community. The benefits of mining are mostly offset by the negative impacts of mining according to the perceptions of many community members.

It was further noted that mining activities created income opportunities for the people in the area. The communities where mines are active were benefiting and non-mining communities were neglected.

2.8.4. Employment and community development

Benefits from the mines were directly from employment, access to education and health care services, and indirectly from agriculture and subsistence businesses. Mining activities provided significant contributions to the income of the local people employed in agriculture by providing the market to their agricultural products (Kitula, 2005).

The participation of local community in the workforce may be lower because of the reluctance of companies to hire local residents. The reason for this reluctance is because the mine employers have a perception that it is difficult to deal with the local workers because they occasionally leave work, while migrants from outside usually live on-site and work consistently throughout the year.

Local residents experience the direct impact of the local environment that makes their lives difficult and create tension between them and the mining companies, which often results in conflicts. For instance, local residents blocked the road to the mine and the mine fired all local workers. Finally, in case of an accident, it is easier to disguise it when only non-local workers are involved (Yang et al., 2019).

Mine operators and local officials try to avoid penalties by keeping silent about accidents and casualties. Mining companies pay families of victims to sign agreements to settle the matter and promise not to speak to outsiders. For non-local workers, the purpose of the lump sum payment is to bring the matter to a close, as the family will leave the site. In the case of the local worker, the family may come back to the mine and ask for more in case of life difficulties (Yang et al., 2019).

Mining can create direct employment opportunities and indirect economic opportunities such as transportation, supply of groceries, house rental, and restaurant services. In general job opportunities and other economic benefits have decreased for local communities (Yang et al., 2019).

2.8.5. Environment and health

Environmental impacts include diversion of rivers, water siltation, landscape degradation, deforestation, destruction of aquatic life habitat, contamination, unfavourable land for agricultural activities and adverse impacts on the livestock and wildlife.

According to previous studies (Kitula, 2005) conducted in Tanzania, it was indicated that mining provided small contributions to the local communities around the mining operations, yet mining activities were considered as the major causes of pollution. Communities complained about water pollution, dust, and damages to buildings from mine-induced explosions.

Environmental pollution may not be perceived as an economic loss (Bismarck and Darkoh, 2015), in their study on the socio-economic and environmental impacts of mining in Botswana, found that environmental effects of the mining operations on the human and physical environment in Selebi-Phikwe and surrounding areas are severe. Air pollution is the main health problem that was linked to mining activities in the area, where most people suffer from cough, asthma, influenza, chest pains and tuberculosis. It was proven by the health problems experienced by people, the destruction of vegetation, and pollution of soil and water.

Disappearance of vegetation and soil contamination due to these negative impacts result in destruction of crops, grasses and trees. The discharged wastewater is sometimes not properly managed and treated, which then flows into streams and rivers where the livestock graze and drink in the area (Bismarck et al., 2015).

Air pollution has rendered the residential land unsuitable for settlement. The population increases due to the inflow of people from other areas, migration and natural increase, which led to the development of squatter settlements at the periphery of the town. These informal or squatter settlements put more pressure on the social infrastructure such as schools, water and health services (Bismarck et al., 2015).

Squatter settlements contribute to problems such as poor sanitation, poor housing infrastructure, destruction of vegetation, and haphazard building structures. The small business sector attracts investments and contribute immensely, but it is not sufficient due to factors such as uncertainty in the future of the mine, and environmental problems.

The government has policies but has not been able to implement and enforce compliance and remedial actions. It has been claimed that pollution has been reduced. However, these claims were in the mining report, as the mining sector, on whom the government relies to report, monitors the points. The management of the company does not work hand in hand with the community in matters of common interest. The meetings are mostly between the executives of the company and town council.

2.9. Chapter summary

Previous studies have shown that the classification of strategic and critical minerals is important, as it benefits developed countries (USGS, 2016; NSTC, 2016; EU, 2014; BGS, 2015). The compiled list of strategic and critical minerals and raw materials is continuously being updated and revised as circumstances change in dynamic markets. Different assessment methods are applied in the screening and classification of these minerals. The three main categories in the classification are economic importance, risk of supply, and impact in the nation's security and economy. Additional factors for screening and classification in developed countries are production growth to highlight the growing importance of minerals, market dynamics dealing with price volatility and stability of the market, and net import reliance.

The literature review provided fundamental knowledge on the main objective of the research study; namely, to develop a framework to classify minerals as strategic and critical, including the socio-economic impacts of mining relevant to the South African context. The pertinent aspects to the country are electricity, expertise and technology, availability of minerals, policy, geopolitical factors, and labour issues for the risk category.

The impacted aspects are employment, community, environment, and supply and demand factors. Finally, the aspects for economic importance are utilisation, infrastructure, income and investment. It is expected that the South African economy will benefit from mineral resources that have been declared strategic and critical in order to enhance its economic and strategic position.

Based on the guiding approach and literature review, qualitative and quantitative methods, which are presented in chapter three, will be used in the research study. A survey questionnaire was administered for the socio-economic impact category of the classification of strategic and critical minerals, while the three valuation methods, namely criticality matrix, geopolitical risk methods, and EU methods are mostly applied in the classification for the risk and economic importance category of the framework.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

The framework for strategic and critical minerals is a broad topic, which requires detailed investigation and studies including all relevant information in the country. This section discusses the design and methods that are were for assessment and development of the framework on strategic and critical minerals in the South African context.

3.2. Research approach

Qualitative and quantitative methods are used in the proposed research. Qualitative research is mostly focused on understanding social issues in the community regarding their personal experiences that affect and lead them to do things the way they do. It further provides information to develop ideas for potential quantitative research as it can be structured or unstructured during the data collection.

Respondents were selected according to the specific local mining community area and were given the questionnaire to complete, while others were individually interviewed. Quantitative research is mostly from observations, which are used to quantify the research problem by generating data from the survey questionnaire (Blaxter et al., 2001).

The research, pertaining to the methods, consists of a literature review and statistical analysis. It includes assessment methods that are used for strategic and critical minerals from developed countries. Previous studies conducted on strategic and critical minerals and South African literature such as books, articles including articles from researchers and consultants have been used in the research study.

Information collected from the local communities was transformed into data to be used for statistical analysis. The data generated from the completed and collected survey questionnaire from different local mining communities was used for statistical analysis to assess socio-economic impacts.

The intention of the qualitative and quantitative investigation is to set up an easily formulated analytical framework with items of choice which will permit evaluation of a mineral into various levels of impact or contribution, which is one section of the total framework.

In addition, the qualitative and semi-quantitative investigations using a “Criticality Matrix” method is applied to assess strategic and critical minerals. The criticality matrix methodology is a conceptual framework for evaluating a mineral’s strategic and critical status in a balanced manner according to a variety of circumstances and parameters. This study is focusing mostly on the short to medium-term impacts of the strategic and critical position of a mineral in the country.

The total framework will therefore provide an integrated evaluation of both qualitative and quantitative factors to assess the criticality or strategic status of a mineral.

3.3. Research design

The research design includes a survey questionnaire using the Likert scale consisting of four sections: 1) personal characteristics; 2) employment and economic activities; 3) community projects and environment; and 4) settlement.

1. *Personal characteristics*: Participants were asked to indicate the geographical location of their community, and their gender, age, level of education, total number of their household members and dependants, their relationship in the household, and their household’s main source of income.

2. *Employment and economic activities*: Respondents were asked to indicate the status of their employment, and to assess the level at which improved quality of life, increased employment in the community, new business opportunities in the area; more tradesmen in the area, training to work in the mines and an improvement in skills; and increased employment from indirect mining-related companies have positively impacted their local community because of the mining operations.

3. *Community projects and environment:* Participants were asked to indicate whether different projects or improvements such as newly built and improved roads, new recreational facilities (sportsgrounds, parks, etc), new clinics and schools, government policy driving improvements, and improved social life status (corporate social responsibility) were experienced in their community because of the mines in their area. They were further asked to assess and indicate the level at which improved health services, educational facilities, and bursaries and scholarships have positively impacted their local community because of the mining operations. In addition, respondents were asked to indicate the level at which pollution (dust, noise, waste, and water), community protests, damaged houses, and the impact of labour protests on work function have negatively impacted their local community because of the mining operations. Respondents also had an option to write other positive or negative impacts not addressed by the different questions.

4. *Settlement*: Participants were asked to indicate the status of their settlement in the area, and to assess and indicate the level at which resettlement to better areas, compensation for displacement, and adequate schools and houses built have positively impacted their local community because of the mining operations in their area. They were further asked to assess and indicate the level at which increased informal settlement, higher rental and house prices,

increased population, and inadequate infrastructure and poor services have negatively impacted their local community because of the mining operations. Respondents also had the general option to write other positive or negative impacts not addressed by the different questions.

The questionnaire (see Appendix A) was administered to the employees and communities around the mines. Data was collected from relevant people in the local communities to assess their perceptions of the socio-economic impacts of mining.

The quantitative method was used to quantify the research on strategic and critical minerals. A study identified frameworks from different countries such as the US, the EU, and the United Nations (UN).

A range of valuation methods on strategic and critical minerals or resources reviewed for assessment include the Anderson's geopolitical risk assessment model, NRC method – Criticality Matrix (The National Research Council affiliated to the National Academy of Sciences of the United States of America), DoE method (USA department of Energy), DoD method (US Department of Defence), BGS method (British Geological Survey), USGS method (US Geological Survey), EU method, UNEP method (United Nations Environment Program), and BGR/ISI/RWI method (Federal Institute of Geosciences and Raw Materials).

The study utilised three valuation methods, namely NRC method (criticality matrix), geopolitical risk assessment method, and EU method. These methods are more focused on several aspects relevant to the South African context, such as geopolitical risks, economic importance and availability.

3.4. Population and sampling

The study used data collected from different areas in the four provinces, namely Gauteng, North-West, Mpumalanga and Limpopo. Most of the mining activities and contribution in the mining industry are from these four provinces. A random sampling method was conducted in the local communities in the mining and utilisation areas. This was done to avoid bias.

Communities from the mining towns, townships, and rural and informal settlements participated in the survey. The population of relevant residents and employees from local communities were randomly selected to complete the questionnaire (Appendix A).

A sample size of eight hundred questionnaires were distributed in four provinces, namely, Gauteng, North-West, Mpumalanga and Limpopo (Table 3.1). Mining sector contributes to the provincial economies of South Africa. Limpopo, Mpumalanga, North-West and Gauteng are the most contributing mining provinces (MCSA, 2018). The general meeting places of the communities such as malls, shopping complexes, churches and adult basic education centres were used to distribute the questionnaire. These questionnaires were distributed to males, females, employed and unemployed, different age group and education level, and households with different source of income.

The questions in the survey are related to their community, environment, economic activities and local mining operations. The aim of the questionnaire was to establish the socio-economic impacts and benefits as perceived and experienced by the communities in the local mining areas. The focus was on the minerals that promote beneficiation and industrialisation in South Africa, such as precious and base minerals.

Table 3.1:Mining community, province and commodity of the sample

Community	Province	Commodity
Rand West City	Gauteng	Gold
Madibeng and Bojanala	North-West	Platinum
Greater Tubatse	Limpopo	Chrome
Victor Khanye	Mpumalanga	Coal

Eight hundred participants were targeted mostly from selected communities around the mines mining different commodities. These local mining communities are the West Rand (Rand West City) in Gauteng, Bojanala Platinum (Madibeng) in North-West, Greater Tubatse in Limpopo and Nkangala (Victor Khanye) in Mpumalanga. These communities have been selected because of the contribution of their provinces to the mining industry and experiences of the mining activities in the said communities around the mines. These mines are also operations that mine minerals where many people are employed.

Minerals that are considered in the research study include gold, platinum group metals, rare earth elements, diamonds, silver, chrome, iron ore, manganese, coal, nickel, and vanadium. These minerals are important and contribute both in GDP terms and foreign investment to the mining industry of South Africa.

3.5. Data collection

Data have been sourced from mining personnel, government institutions, mineral resource sectors and local communities in the mining and utilisation areas. Different government institutions such as Statistics South Africa (StatsSA), the Department of Mineral Resources (DMR), the Department of Energy (DOE) which are combined into Department of Mineral Resources and Energy (DMRE), the National Treasury (NT) and Richards Bay Coal Terminal (RBCT) collate mining industry information which include data on export and import figures of minerals, contribution to the economy, revenue and mining and production volumes. Most of the statistical data, such as production outputs, resources and reserves, and socio-economic information, have been published and are readily available in the public domain.

A survey questionnaire (see Appendix A) was compiled and administered to the local communities and mining employees. Data was collected consistently from different participants in the communities around the mines. The number of questionnaires distributed to participants in the local mining communities were 800, and 690 were completed and returned, which indicates a response rate of 86%.

The questionnaire is related to the socio-economic impacts of the mining operations in the mining communities.

3.6. Data analysis and instrumentation

A framework on strategic and critical minerals of South Africa based on three categories (i.e., socio-economic impact, risk and economic importance) was developed and a list of these minerals generated. Assessment methods for strategic and critical minerals used in the analysis are the EU method, Criticality Matrix, and the geopolitical risk assessment model.

Data collected from the local communities have been taken through preparation, analyses and processing. Statistical analysis such as descriptive statistics, correlations, comparisons, and related tests were applied to analyse the data.

Statistical departments of the University of South Africa (Unisa) and North-West University (NWU) have been consulted in the design of the questionnaires as well as analyses. The required data was captured in a questionnaire. The SPSS (Statistical Package for Social Sciences) software was used as a tool to perform statistical analysis because it is capable of analysing large amounts of data.

3.7. Reliability and validity

It is important for data in the research findings to be reliable and valid. Group meetings and sample bias were avoided to ensure reliability and validity of the sample. The study applied assessment methods (NRC method (criticality matrix), geopolitical risk assessment method, and EU method) that are tested and were used previously in other countries to ensure that the instruments measure what they are supposed to measure. These methods were modified according to the South African context to develop a framework. A software package was used to eliminate human error and ensure validity. Questionnaires completed incorrectly or not as planned were discarded. Statistical methods (correlations, coefficient alpha and spearman correction) were used to assess the reliability and validity of the data collected.

3.8. Ethical considerations

The research involved a questionnaire that was completed by local communities in the mining areas. Willing participants were informed about the survey and requested to complete the questionnaire without any cohesion.

Participation was voluntary and there was no penalty or loss of benefit for non-participation. It was anonymous and no personal identifiable information was required. The research required ethical considerations, as it involved people. The research work was conducted in accordance with the ethical procedures of the university. Ethical clearance (ERC Reference #:2019/CSET_SOE/ID/001) permission was applied for as required and granted for the study to be conducted.

3.9. Limitations and delimitations

The study focused on the minerals that contribute or have the potential to contribute to the economy and those that are likely to be listed as strategic and critical for South Africa. These are the minerals that contribute the most to the economy of the country to address poverty, inequality and unemployment. Employment numbers within the communities for different commodities were considered. Some of the areas that were accessible and mining minerals that are of interest in the study were considered. Minerals of interest include gold, platinum group minerals, diamond, chrome, coal, iron ore, manganese, copper, vanadium, lithium and rare earth elements (REE).

Different assessment methods of strategic and critical minerals or resources were used on these minerals. The methods that were accepted and used were those applicable in the South African context considering the available mineral resources and reserves. A survey questionnaire was only administered to the local communities within the mining operations that have a history of employing many people such as gold, platinum group metals and coal mines, which make a significant and potential contribution to the economy. People not residing or working in the selected communities were excluded.

3.10. Chapter summary

The research approach and design are aligned with the objectives of the research study and utilises methods for the classification of strategic and critical minerals according to the main categories, namely economic importance, risk and impacts. Minerals are identified and screened according to their availability, abundance, viability, substitution, impact and contribution to the South African economy to determine their potential to be strategic and critical to the country. The criticality matrix methodology is applied to assess and classify strategic and critical minerals.

The socio-economic impacts of mining activities on local communities cannot be ignored in developing a framework that can be used to classify minerals as strategic and critical in South Africa. Valuation methods on strategic and critical minerals or resources are used to assess selected minerals in developing the framework. The selected assessment methods, namely (NRC – criticality matrix, geopolitical risk assessment, and EU method) were applied and used previously in other countries. These methods are more applicable to and focused on several aspects that are relevant to the South African context.

Data was collected from participants in local communities in different provinces by using a survey questionnaire. Exploratory data analysis results discussing the characteristics of the sample and profile of the participants are presented in Chapters 4 and 5. In addition, mineral screening processes, the stages of evaluation and parameters for the classification of strategic and critical minerals are also discussed in Chapter 4 and criticality matrix methodology in Chapter 6.

CHAPTER 4: SAMPLE CHARACTERISATION AND SCREENING PROCESS

4.1. Introduction

The study used a survey questionnaire that was compiled and distributed to local community members, where the main objective was to assess their perceptions on the socio-economic impacts of mining in their community. Indicators were used to assess perceptions, namely personal characteristics, employment and economic activities, community projects, and settlement.

In the screening process, potential minerals are identified, quantities of available minerals are assessed, supply and demand of minerals in the markets are considered, employment opportunities, utilisation and beneficiation of minerals are evaluated including their contribution to the economy.

Several contribution aspects of the minerals to the country such as GDP, local and export sales and employment including expenditures from mining such as employee earnings, services, taxes and royalties are considered in the process.

4.2. Exploratory data analysis

4.2.1. Profile of participants

The survey questionnaire was designed by formulating questions around social life, economic activities, environment, and housing and living conditions in the community. It is divided into four sections; namely personal characteristics, employment and economic activities, community projects and environment, and settlement in the community. The tables presented in the section are compiled and sourced by author from the research study.

Section 1 of the survey questionnaire focused on the personal characteristics of the participants, which include the geographical location of their community (i.e., region or province), where they live, their gender, age, level of education, number of household members and dependents, relationship of the participant in the household, and the main source of income of the household. This information is important to understand the role of the participants in the household, their responsibilities, contribution and background. The selected geographical locations of the participants and communities are Gauteng, North-West, Mpumalanga and Limpopo.

A discussion on the employment status of the participants and the economic activity in their community appears in Section 2. The main objective of this Section is to understand the employment sectors, roles and conditions of employment, number of years of employment in the sector, and economic activities, as well as the positive and negative impacts of mining activities in their community.

Positive impacts are the benefits that the communities experience as a result of the mining operation in their area, which include improved quality of life, increased employment in the community, new business opportunities, more tradesmen in the area, training provided to work in the mines and improvement in skills for community members, and increased employment from indirect mining-related companies.

Negative impacts are activities that badly affected the community as a result of the mining operation in the area, which include increased migration of labour, poor environmental conditions (i.e., management, minimisation, disposal, recycling and littering), affected water (i.e., quality, reduction in quantity, contamination and management), shortage of land availability for occupation and farming resulting in conflicts, high crime levels, abuse of drugs and alcohol, and teenage pregnancy affecting the community.

A 5-point Likert-type scale, ranging from (1) to (5), where (1) is extremely low and (5) is extremely high, is used to assess the level of impact of the selected factors on the community as a result of the mining operations in their area.

Mining companies have an obligation to ensure sustainability in the areas in which they operate. The environment and communities are just as important as the profits. The community projects and environment are discussed in Section 3. The main objective of this Section is for the participants to indicate the projects that have been implemented in their community, or improvements that were experienced in their community because of the mines in the area. The projects or improvements include newly built and improved roads, new recreational facilities (i.e., sports grounds, parks, etc), new clinics, government policies on mining that are driving improvements in their area, and improved social status of life (i.e., corporate social responsibility) in the community. A Yes or No response was expected from the experiences of participants in the local community to indicate new projects or improvements where the mines are operating.

In addition, participants are expected to indicate the level at which they have benefited from projects such as improved health services and educational facilities including bursaries and scholarships. The negative impacts will include pollution (i.e., dust, noise, waste and water), community strikes or protests, damaged houses and labour or union strike impacts on work function. A 5-point Likert-type scale, ranging from (1) to (5), where (1) is extremely low and (5) extremely high, is used to assess the level of impact of these positive and negative factors in their community because of the mining operations.

The living conditions of employees in the mines and displacement of communities around the mining operations have been a concern for many people and the government. The status of settlement in the local mining communities is discussed in Section 4.

Participants are expected to indicate the status of their settlement, that is, whether they stay in town, the township, or a rural or informal settlement; number of years they have been living in that community; whether they have been displaced or relocated from where they used to live before because of a mining operation; and whether they were compensated or not. A Yes or No response was expected from the experiences of participants in the local community to indicate compensation and displacement or relocation.

It is important to indicate their experiences of the impacts of mining with regard to settlement to understand perceptions of employees and community members. Positive impacts such as resettlement to better areas, adequate compensation for displacement, and adequate houses and schools that have been built for the community, were assessed. Experiences of negative impacts such as increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services should be indicated by participants. A 5-point Likert-type scale, ranging from (1) to (5), where (1) is extremely low and (5) is extremely high, is being used to assess the level of impact of these positive and negative factors in their community because of the mines.

4.2.2. Personal characteristics

The survey questionnaire was compiled to assess perceptions of local people on the socio-economic impacts of mining in their community according to their personal characteristics and experiences. Personal characteristics assessed are geographical location, gender, age, level of education, number of household members and dependents, relationship in the household, and the household's main source of income.

4.2.2.1. Geographical location

The participants are from the North-West (29%), Gauteng (25.7%), Mpumalanga (23.2%) and Limpopo (21.9%) provinces (see Table 4.1).

Table 4.1: Indicate your geographical location in the community.

		Frequency	Percent
Valid	Gauteng	177	25.7
	North-West	202	29.3
	Limpopo	151	21.9
	Mpumalanga	160	23.2
	Total	690	100

Source: Community responses from the questionnaire.

4.2.2.2. Gender

The mining industry is mostly dominated by males according to MCSA, 2021, the industry employed 96% males and 14% females. Most participants in the community were males at 73% (see Table 4.2).

Table 4.2: Indicate your gender

		Frequency	Percent
Valid	Male	504	73.0
	Female	186	27.0
	Total	690	100

Source: Community responses from the questionnaire.

4.2.2.3. Age

The young people in the community are active, and their participation rate was better than the older people in the survey. The majority (68.6%) of the participants are between 21 and 40 years of age (see Table 4.3).

Table 4.3: Indicate your age on your last birthday

		Frequency	Percent
Valid	< 21 years	7	1.0
	21 - 30 years	233	33.8
	31 - 40 years	240	34.8
	41 - 50 years	65	9.4
	51 - 60 years	101	14.6
	> 60 years	44	6.4
	Total	690	100

Source: Community responses from the questionnaire.

4.2.2.4. Level of education

The mining industry is known to employ most unskilled labourers and few skilled and specialised professionals. Employees in the Paterson grading level A (28%) and B (66%) are mostly unskilled (MTR, 2018). This is probably due to the nature of the job requirements and lack of application of advanced mining technology in the mining industry. Most of the respondents' highest level of education completed is secondary school (65.1%) and tertiary education is the second least at 10.9% (see Table 4.4).

Table 4.4: Indicate the highest level of education you completed

		Frequency	Percent
Valid	Did not attend school	5	0.7
	Primary school	161	23.3
	Secondary school	449	65.1
	University or tertiary education	75	10.9
	Total	690	100

Source: Community responses from the questionnaire.

4.2.2.5. Number of household members and dependents

Most of the respondents (76.8%) stay with two to five people, while respondents staying alone is the least at 7.1%. It is also noted that the percentage of respondents staying with families of more than six people is high at 15.7% (see Table 4.5).

Table 4.5: Indicate the total number of your household members and dependents.

		Frequency	Percent
Valid	1 person	49	7.1
	2-3 people	262	38.0
	4-5 people	268	38.8
	> 6 people	108	15.7
	6 people	2	0.3
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.2.6. Relationship in the household

The majority of the respondents are breadwinners (i.e., people providing a main source of income) in their household at 69.3%, while 14.6% are children in the household (see Table 4.6).

Table 4.6: Indicate your relationship in the household

		Frequency	Percent
Valid	Bread winner	478	69.3
	Spouse	94	13.6
	Son / Daughter	101	14.6
	Other	17	2.5
	Total	690	100

Source: Community responses from the questionnaire.

4.2.2.7. Household's main source of income

The main source of income of the respondents is from a salary at 82.3%, followed by social grants at 9.7% (see Table 4.7). It is noted that less (3.2%) people derive their source of income from their own business.

Table 4.7: Indicate your household's main source of income

		Frequency	Percent
Valid	Salary	568	82.3
	Own business	22	3.2
	Social grant	67	9.7
	Other	32	4.6
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.3. Employment and economic activities

The survey questionnaire was compiled to assess perceptions of local people on the socio-economic impacts of mining in their community according to employment and economic activities. Employment and economic activities assessed are place of work, number of years employed in the job, current work status, position at work including related aspects of the positive and negative impacts of mining.

4.2.3.1. Place of work

Most of the respondents working at the mines are at 55.1%, while those working in other sectors are 31.7%. The percentage of the unemployed is 13.2% (see Table 4.8).

Table 4.8: Indicate your employment status

		Frequency	Percent
Valid	Mining	380	55.1
	Other	219	31.7
	Unemployed	91	13.2
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.2. Numbers of years employed in the job

The percentage of people with five to ten years' service is 41.7%. Respondents with 1 – 4 years' experience is 24.6% (see Table 4.9).

Table 4.9: Indicate your employment status: duration

		Frequency	Percent
Valid	< 1 year	20	2.9
	1-4 years	170	24.6
	5 - 10 years	288	41.7
	> 11 years	124	18.0
	Unemployed	88	12.8
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.3. Current work status

Most respondents are on permanent employed (64.6%) and 21.2% are on contract employment (see Table 4.10).

Table 4.10: Indicate your employment status: Type

		Frequency	Percent
Valid	Permanent	446	64.6
	Contract	146	21.2
	Part-time	8	1.2
	Unemployed	89	12.9
	13	1	0.1
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.4. Position at work

Most of the respondents are general workers at 67.1%, while supervisors are at 11.4%. As expected in the mining area, only 6.2% of the employees are in managerial positions (see Table 4.11).

Table 4.11: Indicate your employment status: position

		Frequency	Percent
Valid	Employee(General workers)	463	67.1
	Supervisor	79	11.4
	Manager	43	6.2
	Director	15	2.2
	Unemployed	90	13.0
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.5. Positive impacts – Improved quality of life

The majority of the respondents agree (53.4%) that mining has positive impacts and improves the quality of life. Almost a third of the respondents are neutral (average – 30.1%) with regard to the positive impacts in improving the quality of life (see Table 4.12).

Table 4.12: Indicate level of benefit: Improved quality of life

		Frequency	Percent
Valid	Extremely low	36	5.2
	Low	77	11.2
	Average	208	30.1
	High	237	34.3
	Extremely high	132	19.1
	Total	690	100

Source: community responses from the questionnaire.

4.2.3.6. Positive impacts – Increased employment

The respondents agree (46.4%) that mining has positive impacts on the community with regard to increased employment from the mines (see Table 4.13).

Table 4.13: Indicate level of benefit: Increased employment

		Frequency	Percent
Valid	Extremely low	52	7.5
	Low	113	16.4
	Average	205	29.7
	High	183	26.5
	Extremely high	137	19.9
	Total	690	100

Source: community responses from the questionnaire.

4.2.3.7. Positive impacts – New business opportunities

46.8% of the respondents do not believe that there are positive impacts from mining with regard to business opportunities. They believe that business opportunities are given to big companies. 34.2% of participants were neutral on the opportunities, as they were aware of their positive impacts but indicated that it is mostly not for the locals (see Table 4.14).

Table 4.14: Indicate level of benefit: New business opportunities

		Frequency	Percent
Valid	Extremely low	91	13.2
	Low	232	33.6
	Average	236	34.2
	High	98	14.2
	Extremely high	33	4.8
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.8. Positive impacts – More tradesmen

Most respondents agree on the positive impacts with regard to the increased number of tradesmen in the community (52.9%) (see Table 4.15). It is clear that mining companies have subjected their employees to training and skills development.

Table 4.15: Indicate level of benefit: More tradesmen

		Frequency	Percent
Valid	Extremely low	48	7.0
	Low	65	9.4
	Average	212	30.7
	High	214	31.0
	Extremely high	151	21.9
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.9. Positive impacts – Training to work in the mines and improvement in skills

The majority of the respondents (74%) agree with the positive impacts of the mines with regard to training to work in the mines (see Table 4.16).

Table 4.16: Training to work in the mines and improvement in skills

		Frequency	Percent
Valid	Extremely low	31	4.5
	Low	58	8.4
	Average	90	13.0
	High	105	15.2
	Extremely high	406	58.8
	Total	690	100

Source: community responses from the questionnaire.

4.2.3.10. Positive impacts – Increased employment from indirect mining-related company

The respondents (36.6%) do not agree that indirect mining-related companies provide increased employment opportunities (see Table 4.17). They believe that these companies bring their own employees to the community. In fact, the situation is that outside contract companies bring their own trained staff.

Table 4.17: Indicate level of benefit: Increased employment from indirect mining-related companies

		Frequency	Percent
Valid	Extremely low	77	11.2
	Low	175	25.4
	Average	238	34.5
	High	142	20.6
	Extremely high	58	8.4
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.11. Negative impacts – Increased migration of labour

Most of the respondents (60.6%) believe that mining brings negative impacts as a result of increased migration of labour in their community (see Table 4.18).

Table 4.18: Indicate level of negative impact: Increased migration of labour

		Frequency	Percent
Valid	Extremely low	31	4.5
	Low	65	9.4
	Average	176	25.5
	High	214	31.0
	Extremely high	204	29.6
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.12. Negative impacts – Environmental conditions

Respondents provided a low (47.7%) to neutral (30%) response to the negative impacts of mining activities on the environment. A few respondents (22.4%) are concerned about the effects of mining on the environment because they stay closer to the mines (less than 5km) and are affected by noise, dust and water spillages from the mines (see Table 4.19).

Table 4.19: Indicate level of negative impact: Environmental conditions

		Frequency	Percent
Valid	Extremely low	146	21.2
	Low	183	26.5
	Average	207	30.0
	High	108	15.7
	Extremely high	46	6.7
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.13. Negative impacts – Water

The majority of respondents (67.5%) are not aware of the negative impacts of mining operations on the water. It is because water is provided by the municipality to the community. A few (17.1%) of them are concerned about the negative impacts of mining on the water (see Table 4.20).

Table 4.20: Indicate level of negative impact: Water

		Frequency	Percent
Valid	Extremely low	332	48.1
	Low	134	19.4
	Average	106	15.4
	High	61	8.8
	Extremely high	57	8.3
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.14. Negative impacts – Land availability

Most respondents (55.1%) are aware of the negative impacts of mining operations on the availability of land in their local community (see Table 4.21) because some community members have been relocated from the mining area.

Table 4.21: Indicate level of negative impact: Land availability

		Frequency	Percent
Valid	Extremely low	40	5.8
	Low	100	14.5
	Average	170	24.6
	High	218	31.6
	Extremely high	162	23.5
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.15. Negative impacts – High crime levels

The majority of the respondents (60.9%) indicated that a high crime level in their community is due to the mining activities, and it has negative impacts. Very few respondents (11.7%) do not associate high crime levels with the mining operations (see Table 4.22).

Table 4.22: Indicate level of negative impact: High crime levels

		Frequency	Percent
Valid	Extremely low	20	2.9
	Low	61	8.8
	Average	188	27.2
	High	178	25.8
	Extremely high	242	35.1
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.3.16. Negative impacts – Abuse of drugs and alcohol

The abuse of drugs and alcohol is perceived to have a negative impact of mining operations in the community. Most respondents (78.7%) believe the behaviour is a result of mines coming into their area (see Table 4.23).

Table 4.23: Indicate level of negative impact: Abuse of drugs and alcohol

		Frequency	Percent
Valid	Extremely low	18	2.6
	Low	45	6.5
	Average	84	12.2
	High	208	30.1
	Extremely high	335	48.6
	Total	690	100

Source: Community responses from the questionnaire.

4.2.3.17. Negative impacts – Teenage pregnancy

Most of the respondents (60.8%) are concerned about the negative impacts of mining with regard to teenage pregnancy. There is a high perception that teenage pregnancy is a result of mining operations in their area (Table 4.24).

Table 4.24: Indicate level of negative impact: Teenage pregnancy

		Frequency	Percent
Valid	Extremely low	18	2.6
	Low	55	8.0
	Average	196	28.4
	High	137	19.9
	Extremely high	282	40.9
	Total	688	99.7
Missing	System	2	0.3
Total		690	100

Source: Community responses from the questionnaire.

4.2.4. Community projects and environment

The survey questionnaire assessed perceptions of local people on the socio-economic impacts of mining in their community according to community projects and environmental conditions.

Community projects and environmental conditions assessed are newly built roads and improved roads, new recreational facilities, new clinics, government policies and social life status including related aspects of the positive and negative impacts of mining.

4.2.4.1. Newly built and improved roads

Most respondents (71.9%) indicated that they are not aware of newly built and improved roads by the mining companies in their area (see Table 4.25).

Table 4.25: Indicate whether there are newly built and improved roads

		Frequency	Percent
Valid	Yes	191	27.7
	No	496	71.9
	Total	687	99.6
Missing	System	3	0.4
Total		690	100

Source: Community responses from the questionnaire.

4.2.4.2. New recreational facilities

Almost half the respondents (49.3%) are aware of recreational facilities built by the mines and the other half (50.4%) is not aware or do not perceive that mines will build new facilities for the community (see Table 4.26). They believe facilities are built by the government.

Table 4.26: Indicate whether there are new recreational facilities

		Frequency	Percent
Valid	Yes	340	49.3
	No	348	50.4
	Total	688	99.7
Missing	System	2	0.3
Total		690	100

Source: Community responses from the questionnaire.

4.2.4.3. New clinics

Almost more than half of the respondents (51.0%) are aware of recreational facilities built by the mines and the other half (48.7%) is not aware or do not perceive that mines will build new clinics for the community (see Table 4.27). This latter view is because clinics in communities are government run to which the mining companies contribute. Only some mines provide self-funded clinics on mining property.

Table 4.27: Indicate whether there are new clinics

		Frequency	Percent
Valid	Yes	352	51.0
	No	336	48.7
	Total	688	99.7
Missing	System	2	0.3
Total		690	100

Source: Community responses from the questionnaire.

4.2.4.4. Government policies are driving improvement in the area

Most of the respondents (60.6%) have a strong perception that government policies are driving improvement in the area and that mining companies cannot make improvements on their own in their community (see Table 4.28). The view is that mining companies do not listen to the communities but will listen to the government officials. In fact, mines are required according to the SLP to install community projects which gives the community the wrong impression.

Table 4.28: Government policies are driving improvement in the area

		Frequency	Percent
Valid	Yes	418	60.6
	No	272	39.4
	Total	690	100

Source: Community responses from the questionnaire.

4.2.4.5. Improved social status

Most of the respondents (66.1%) have a strong perception that there is no improvement of their social status as a result of the mining operations in the area because they still live in a poor community (see Table 4.29).

Table 4.29: Indicate whether there is improved social status

		Frequency	Percent
Valid	Yes	231	33.5
	No	456	66.1
	Total	689	99.6
Missing	System	3	0.4
Total		690	100

Source: Community responses from the questionnaire.

4.2.4.6. Positive impacts – Improved health services

The respondents (29.9%) are neutral about the positive impacts experienced by the community as a result of the presence of the mine in their area. It is further noted that only 28.6% have indicated the awareness of the benefits of mining with regard to improved health services. Some respondents (41%) do not believe that the community has benefited from improved health services as a result of the mining operations in their community (see Table 4.30). Part of the problem is because people still travel long distances to receive health care.

Table 4.30: Indicate level of benefit: Improved health services

		Frequency	Percent
Valid	Extremely low	129	18.7
	Low	158	22.9
	Average	206	29.9
	High	140	20.3
	Extremely high	57	8.3
	Total	690	100

Source: Community responses from the questionnaire.

4.2.4.7. Positive impacts – Educational facilities

The respondents (41.4%) indicated that education facilities as a result of a mining operation in their community have positive impacts. However, a low rating of 31.9% on the positive impacts was noted from the respondents (see Table 4.31). They are concerned about access to the facilities.

Table 4.31: Indicate level of benefit: Educational facilities

		Frequency	Percent
Valid	Extremely low	89	12.9
	Low	131	19.0
	Average	183	26.5
	High	170	24.6
	Extremely high	116	16.8
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.4.8. Positive impacts – Bursaries and scholarships

The majority of the respondents (70.8%) indicated a low rating with regard to the positive impacts of bursaries and scholarships in their community due to the presence of the mining operation in their area. A low percentage (12.1%) of the respondents indicated a high rating of the positive impacts of a mining operation in their community (see Table 4.32).

Table 4.32: Indicate level of benefit: Bursaries and scholarship

		Frequency	Percent
Valid	Extremely low	355	51.4
	Low	134	19.4
	Average	118	17.1
	High	48	7.0
	Extremely high	35	5.1
	Total	690	100

Source: Community responses from the questionnaire.

4.2.4.9. Negative impacts – Pollution

The participants' perception on the negative impacts was also explored. Some respondents (43.8%) believed pollution has a low negative impact in their community as result of the mining operation. They believe water from the mine do not mix with drinking water supplied by the municipality. A low percentage (26.2%) of respondents believed that pollution due to the mines has a high negative impact in their community because water streams are polluted. Thirty percent of the respondents are neutral about the negative impact of pollution (see Table 4.33).

Table 4.33: Indicate level of negative impact: Pollution

		Frequency	Percent
Valid	Extremely low	116	16.8
	Low	186	27.0
	Average	207	30.0
	High	99	14.3
	Extremely high	82	11.9
	Total	690	100

Source: Community responses from the questionnaire.

4.2.4.10. Negative impacts – Community strikes or protests

The majority of the respondents (62.1%) are concerned about the high negative impacts of community strikes or protests in their community due to the mining operations in the area. A low percentage (17.5%) of respondents have indicated a low negative impact of community strikes due to mining (see Table 4.34).

Table 4.34: Indicate level of negative impact: Community strikes or protests

		Frequency	Percent
Valid	Extremely low	49	7.1
	Low	72	10.4
	Average	139	20.1

	High	219	31.7
	Extremely high	210	30.4
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.4.11. Negative impacts – Damaged houses

The majority of the respondents (78.5%) have indicated a low negative impact of damages to their houses due the mining operations in the area. A low number of respondents (11.3%) indicated a high negative impact of damaged houses as a result of blasting due to the mine (see Table 4.35).

Table 4.35: Indicate level of negative impact: Damaged houses

		Frequency	Percent
Valid	Extremely low	404	58.6
	Low	137	19.9
	Average	71	10.3
	High	36	5.2
	Extremely high	42	6.1
	Total	690	100

Source: Community responses from the questionnaire.

4.2.4.12. Negative impacts – Labour/Union strike impact on work function

The labour strikes have an impact on the work function. Some of the respondents (42.9%) have indicated a low negative impact of labour strikes on work function in the community due to the mines in the area because strikes mostly take place closer to the mines.

A low percentage (24.2%) of respondents indicated a high negative impact of labour strikes on the work function due to the mines because protests will sometimes block roads. Approximately 33% of the respondents are neutral with regard to the negative impact of labour strikes on the work function (see Table 4.36).

Table 4.36: Indicate level of negative impact: Labour strike impact on work function

		Frequency	Percent
Valid	Extremely low	105	15.2
	Low	191	27.7
	Average	227	32.9
	High	101	14.6
	Extremely high	66	9.6
	Total	690	100

Source: Community responses from the questionnaire.

4.2.5. Settlement

This section is related to the status of settlement of the local community. The responses about the perceptions of positive and negative impacts of the mining operations in their community with regard to their settlement are considered. Settlement aspects assessed are place of stay, years living in the community, displacement, and compensation including related aspects of the positive and negative impacts of mining.

4.2.5.1. Where do you stay

Most respondents (38.7%) are staying in the township, followed by rural (23.0%), informal (21.2%) and the town (17%) (see Table 4.37).

Table 4.37: Indicate your status of settlement: Area

		Frequency	Percent
Valid	Town	117	17.0
	Township	267	38.7
	Rural	159	23.0
	Informal	146	21.2
	Total	689	99.9

Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.5.2. Number of years living in the community

The majority of the respondents (62.6%) have been living for more than eleven years in the local community where mining companies are operating (see Table 4.38).

Table 4.38: Number of years living in the community

		Frequency	Percent
Valid	< 1 year	5	0.7
	1 - 4 years	77	11.2
	5 -10 years	174	25.2
	> 11 years	432	62.6
	5	2	0.3
	Total	690	100

Source: Community responses from the questionnaire.

4.2.5.3. Displacement because of mines

The majority of the respondents (94.1%) have indicated that they have not been displaced from where they used to stay because of the mining operations (see Table 4.39). Some respondents were compensated for displacement.

Table 4.39: Have you been displaced because of the mine

		Frequency	Percent
Valid	Yes	40	5.8
	No	649	94.1
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.5.4. Compensated for displacement

The majority of the respondents (95.5%) indicated that they have not been compensated for displacement as most of them were not displaced by the mines (see Table 4.40).

Table 4.40: Were you compensated for displacement

		Frequency	Percent
Valid	Yes	28	4.1
	No	659	95.5
	Total	687	99.6
Missing	System	3	0.4
Total		690	100

Source: Community responses from the questionnaire.

4.2.5.5. Positive impacts – Resettlement to better areas

The majority of the respondents (74.2%) have indicated low positive impacts of resettlement to better areas due the mining operations in the area. Most community members have not been moved by the mines (see Table 4.41).

Table 4.41: Indicate level of benefit: Resettlement to better areas

		Frequency	Percent
Valid	Extremely low	449	65.1
	Low	63	9.1
	Average	91	13.2
	High	47	6.8
	Extremely high	39	5.7
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.5.6. Positive impacts – Adequate compensation for displacement

The majority of the respondents (84.6%) have indicated low positive impacts with regard to adequate compensation for displacement because the mining operations did not displace them (see Table 4.42).

Table 4.42: Indicate level of benefit: Adequate compensation for displacement

		Frequency	Percent
Valid	Extremely low	506	73.3
	Low	78	11.3
	Average	66	9.6
	High	26	3.8
	Extremely high	13	1.9
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.5.7. Positive impacts – Adequate schools have been built

Some respondents (37.5%) indicated low positive impacts with regard to adequate schools built in the community as a result of a mining operations in their community because some schools are overcrowded. However, a rating of 33.9% on the positive impacts was noted from other respondents (see Table 4.43).

Table 4.43: Indicate level of benefit: Adequate schools have been built

		Frequency	Percent
Valid	Extremely low	121	17.5
	Low	138	20.0
	Average	197	28.6
	High	151	21.9
	Extremely high	83	12.0
	Total	690	100

Source: Community responses from the questionnaire.

4.2.5.8. Positive impacts – Adequate houses have been built

The majority of the respondents (68.2%) have indicated low positive impacts with regard to adequate houses built in the community as a result of a mining operation in their community. However, a rating of 13% on the positive impacts was noted from the respondents (see Table 4.44).

Table 4.44: Indicate level of benefit: Adequate houses have been built

		Frequency	Percent
Valid	Extremely low	348	50.4
	Low	123	17.8
	Average	129	18.7
	High	56	8.1
	Extremely high	34	4.9
	Total	690	100

Source: Community responses from the questionnaire.

4.2.5.9. Negative impacts – Increased informal settlement

The majority of the respondents (63.8%) have indicated high negative impacts of increased informal settlements in the community as a result of a mining operation in their area. However, a low rating of 13.4% on the negative impacts was noted from the respondents (see Table 4.45).

Table 4.45: Indicate level of negative impact: Increased informal settlements

		Frequency	Percent
Valid	Extremely low	48	7.0
	Low	44	6.4
	Average	157	22.8
	High	196	28.4
	Extremely	244	35.4
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.5.10. Negative impacts – Higher rental and house prices

The majority of the respondents (79.4%) have indicated high negative impacts of higher rental and house prices in the community as a result of mining operations in their area. However, a low rating of 9.1% on the negative impacts was noted from the respondents (see Table 4.46).

Table 4.46: Indicate level of negative impact: Higher rental and house prices

		Frequency	Percent
Valid	Extremely low	29	4.2
	Low	34	4.9
	Average	78	11.3
	High	193	28.0
	Extremely high	355	51.4
	Total	689	99.9
Missing	System	1	0.1
Total		690	100

Source: Community responses from the questionnaire.

4.2.5.11. Negative impacts – Increased population

Most of the respondents (67.2%) have indicated high negative impacts of increased population (i.e., migrants) in the community as a result of a mining operations in their area. However, a low rating of 6.7% on the negative impacts was noted from the respondents (see Table 4.47).

Table 4.47: Indicate level of negative impact: Increased population

		Frequency	Percent
Valid	Extremely low	17	2.5
	Low	29	4.2
	Average	180	26.1
	High	205	29.7
	Extremely high	259	37.5
	Total	690	100

Source: Community responses from the questionnaire.

4.2.5.12. Negative impacts – Inadequate infrastructure and poor services

The majority of the respondents (73.9%) have indicated high negative impacts of inadequate infrastructure and poor services in the community as a result of a mining operation in their area due to poor roads and leaking water pipes. It is further noted that 53.2% of the respondents have indicated an extremely high negative impact of the inadequate infrastructure and poor services associated with damaged waste pipes and sewage spillages. A low rating of 6.7% on the negative impacts was noted from the respondents (see Table 4.48).

Table 4.48: Indicate level of negative impact: Inadequate infrastructure and poor services

		Frequency	Percent
Valid	Extremely low	29	4.2
	Low	60	8.7
	Average	91	13.2
	High	143	20.7
	Extremely high	367	53.2
	Total	690	100

Source: Community responses from the questionnaire.

4.3. Screening process of strategic and critical minerals

4.3.1. Parameters of the framework for strategic and critical minerals

Mining is an intensive electricity-usage industry and shortages can result in closure of operations. Many people may lose their jobs due to unreliable and unavailable power supply which will lead to low production and closure of some sections of the operation. Electricity is required in mining exploration to develop new mining operations.

Exploration activities will provide opportunities to discover new ground and resources for the mining operations. New mines ensure discovery and availability of minerals which directly increase the supply of resources. Shortages of production results in an adverse impact of supply, lack of supply, risk of supply, and shortfall of supply to domestic and international markets.

A transition from fossil fuels and technological improvements is required to address impacts on the economy and communities.

Local communities and employees are important for the success of the mining operation. Involving a community in the mining industry will ensure a mine to secure a social licence to operate. Mining companies are required to submit a social and labour plan (SLP) for their operations. An SLP is a social contract towards sustainability and development of the community. Companies contribute towards the corporate social investment which is mostly directed to the communities. A local community will be affected by mining activities due to the nature of the operation, starting from exploration to mine rehabilitation. Factors which continue to affect the community are health, safety (fatalities), environment (pollution, noise, and dust), land and water, disputes, riots, sustainability, and socio-economic issues.

A tripartite team which includes the community, government and mining companies is responsible for addressing and resolving concerns brought on by mining activities. There are power relations which must be managed properly between the government, community and mining companies to ensure smooth operation of the mine.

Government is responsible for creating a favourable business environment to attract investment and sustainability, as well as ensuring the well-being of its citizens. This can be achieved through favourable and clear policies. Certainty is required in mining to ensure a stable and predictable policy and regulatory framework. A successful mining industry requires competent administrators, reliable systems and a competitive policy environment. The application for mining permits and rights, monitoring of mining activities by inspectors, and documentation require competent administrators. A reliable and easily accessible system is important to attract investment.

The state should be familiar and recognise the importance of investing into the country's geological endowment, such as the Council for Geoscience. The Council for Geoscience must lead the geological research, regional surveys and mapping, and the record of historical exploration data which should be accessible and made freely available to prospective explorers. The Council should further develop and adopt an internationally competitive policy environment because of the nature of the resources and status in the global market. Clarity and certainty are crucial in the policy framework and regulation, compliance, taxation, discretionary powers, vulnerability and opportunities for intervention. The aspirations and plans of the government should be clearly articulated and updated in the National Development Plan in order to achieve maximum benefits from the mineral resources for the country and its citizens.

The South African mining industry has a history of intensive manual labour. Previously, lack of education, skills and technology led to high employment of unskilled labour in the industry. Main issues such as costs, strikes or protest actions, salary and skills, affect the profitability and survival of mining operations. These issues are pertinent in the successful mining and utilisation of mineral resources in the country. The government should develop and adopt a favourable environment as well as policies for both the employees and employers. A balance is required to ensure that labour costs do not render mining operations unprofitable and that workers are not exploited.

The geographical location of mineral resources to the market and point of utilisation is important. Mineralisation of the ore bodies is naturally controlled, and minerals are deposited in different locations according to the mode of the depositional environment. Transportation of mineral deposits to the point of utilisation and market is through the roads, rail and ports. The development of this infrastructure is a requirement for the successful, thriving and competitive mining industry.

Parameters of the framework (see Table 4.49 a & b) affect the mining industry and the country. These are important in the assessment of strategic and critical minerals and are applied in the screening process to develop the framework for the classification in the South African context.

Table 4.49: Summarised table of the parameters of the framework and their impacts.

PARAMETERS OF THE FRAMEWORK	**IMPACTS AND CONTRIBUTING FACTORS**
Electricity	Reliable electricity supply Electricity prices Power generation Renewable energy
Availability of resources	Abundance of mineral reserves (resource endowment) Geology, technical, environment, politics, mineral regulation, promotion, economics
Impact of supply	Production growth and new mines Shortage and supply risk Market concentration and proximity to the market Supply to domestic & international markets
Demand	Importance of use, consumption, population trends, policies, market dynamics, substitutes, technological changes, modernisation, foreign export reliance, international exports
Utilisation	Manufacturing Processing and refining Beneficiation Industrialisation
Geopolitical risks	Geographical location Political environment Share of global production
Income	Earnings Gross Domestic Product

Continued: Summarised table of the parameters of the framework

PARAMETERS OF THE FRAMEWORK	IMPACTS AND CONTRIBUTING FACTORS
Employment	Job creation Training and skills development
Community	Socio-economic factors Social licence to operate Corporate social investment Sustainability & projects
Expertise & Technology in Mining	Comparative and competitive strategies Machinery and equipment
Investment	Investors Capital investment
Mineral policy	Policy and regulatory framework Competitive policy environment Competent administrators Reliable and accessible systems
Labour and costs	Education, skills and technology Profitability and costs Protest actions
Environment	Rehabilitation Governance Sustainability Climate change
Infrastructure and logistics	Geographical location and market Road, rail and ports

4.3.2. Stages of mineral evaluation in the classification of strategic and critical minerals

The minerals are classified into different stages for evaluation within their categories towards developing a framework. The seven stages for evaluation are identification and availability of a mineral; importance of use and reliance; production and growth; resources and reserves; marketing and demand; a team of subject matter experts; and finally, the investment of the mineral resource (see Figure 4.1).

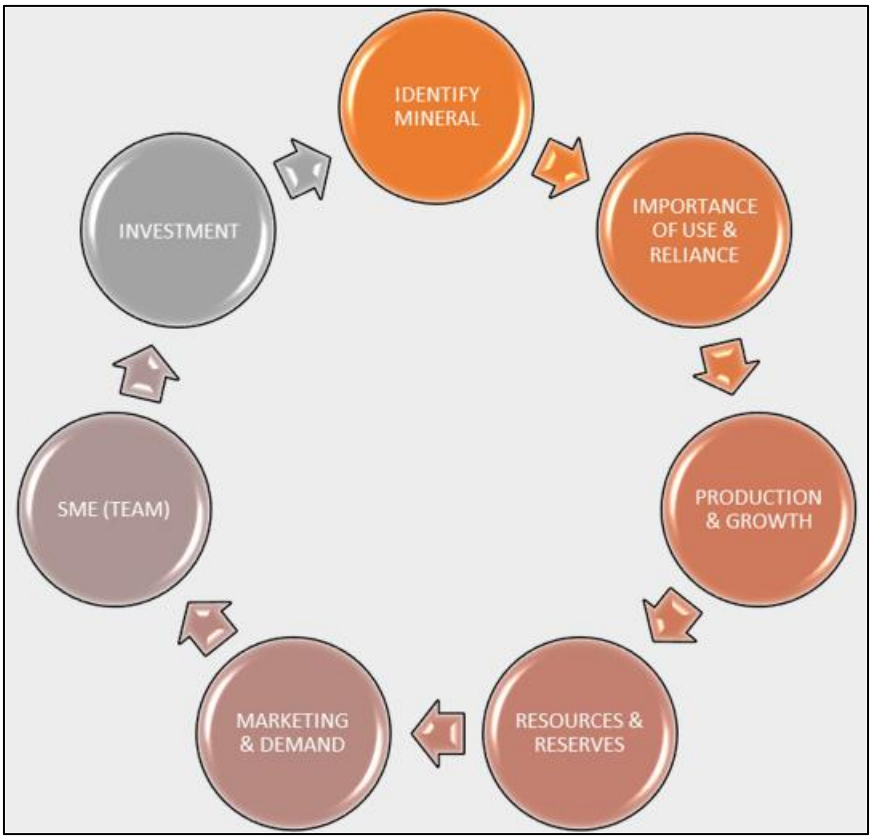


Figure 4.1: Stages of evaluation in the classification of strategic and critical minerals

4.3.3. Associated roles and responsibilities in the different stages

Associated responsibilities and implementation of the process in the different stages of the category method are discussed in detail in the sections that follow.

4.3.3.1. Identify mineral

The first stage in the evaluation towards developing a framework is to identify the mineral and its availability where the mineral is well researched, explored and identified for economic purposes. Mineral identification activities refer to geological mapping, research and development, information gathering, research funding, and mineral resources and reserves evaluation (see Figure 4.2).

Figure 4.2: Identification and availability of a mineral in the classification of strategic and critical minerals

Mineral availability activities refer to the existence of quantity and quality of mineral resources, extraction and processing potential, environmentally and socially acceptable production, government policies and conducive environment, viability to producers, and market acceptance. To ensure accountability and implementation of mineral identification and availability, relevant skills are required. The Council for Geoscience (CGS) is the relevant responsible institution for executing the first stage of identifying all the relevant minerals. Quality research provides the information required for understanding the national, international and global distribution, supply, and demand for energy and mineral resources.

It can also further assess scientific data and inventories of mined and discovered resources, including undiscovered resources. In addition, it serves as the primary screening stage of the strategic and critical minerals.

Identification of minerals and exploration should not be the sole responsibility of the mining companies. The development of new projects and green field projects contribute towards the supply of minerals. Mining companies make drastic decisions during difficult financial times, which affect exploration activities. Companies opt for reducing capital spending, and halting the development of replacement shafts that are required in the medium to long-term to sustain operations and close exploration departments.

4.3.3.2. Importance of use and reliance

The second stage is the importance of use including reliability. Classification and evaluation of these minerals are based on their application and uses, domestic reliance, external reliance, economic contribution, security, and socio-economic and environmental conditions (see Figure 4.3).

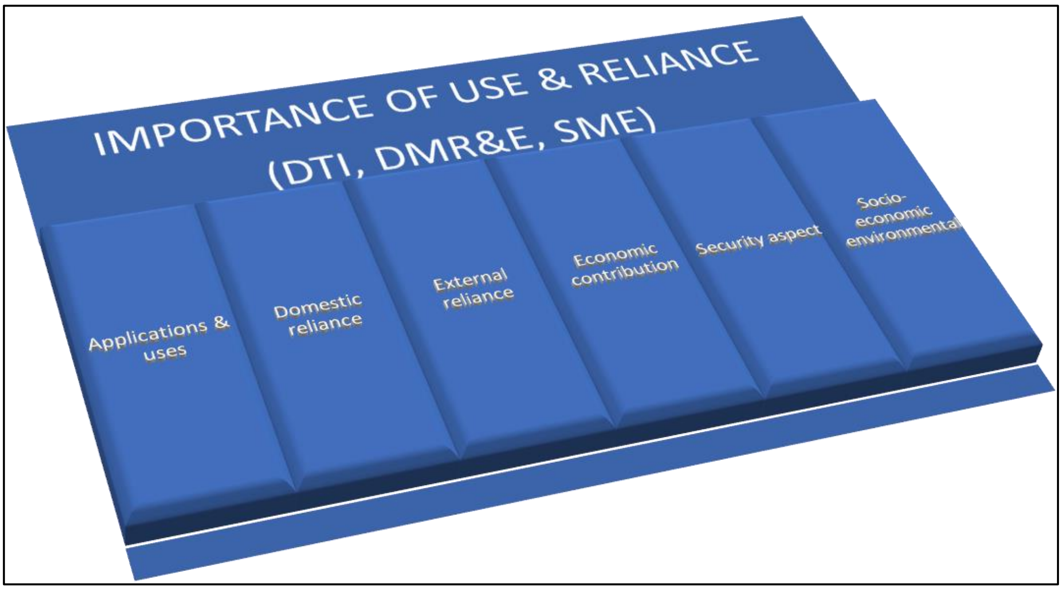


Figure 4.3: Importance of use and reliance in the classification of strategic and critical minerals.

Minerals are needed for specific uses by consumers in the market because they drive the supply and demand. Some of the projects or downstream activities where minerals can be utilised include cement, steel, liquid fuels, electricity, polymers and plastics, and fuel cells. The importance of the minerals can change depending on the technological changes and new requirements. Relevant institutions that can be responsible and capable to ensure implementation are the Department of Trade and Industry (DTI), the Department of Mineral Resources and Energy (DMRE), and the subject matter experts from the industry, and science and technology.

4.3.3.3. Production and growth

The third stage in the evaluation and classification of strategic and critical minerals is production and growth. Important aspects at this stage are mining permits, promotion of mining both nationally and internationally, financial assistance for production and processing, extraction and refining, manufacturing, the number of producers (HHI), producer and supplier relations, and agreements (see Figure 4.4).

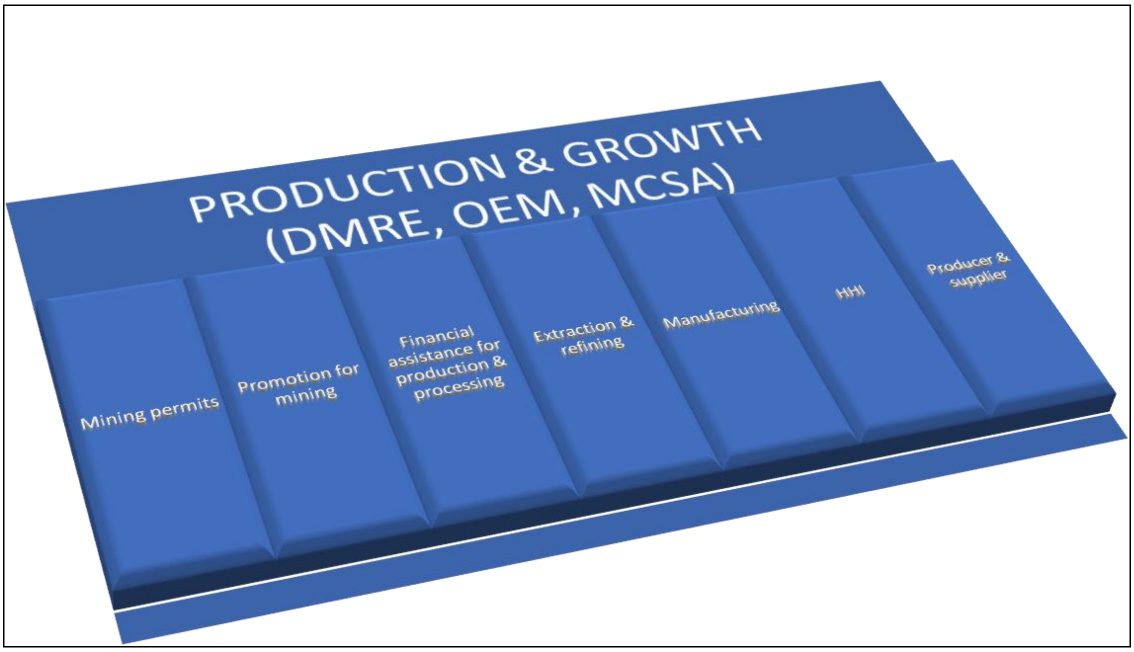


Figure 4.4: Production and growth in the classification of strategic and critical minerals.

The approval and issuing of mining permits are important for mining production and growth of the industry. Production figures will drop, and no new mining production can start without timeous and streamlined issuing of permits. Domestic and global consumption require sufficient production of minerals and growth in the industry. Production should meet overall supply and demand requirements of consumers.

There is a need for financial assistance for production and processing, extraction and refining, investment and infrastructure development to achieve growth. Availability of capital is important for production and growth to develop infrastructure and mining operations. Development of rail, road and port infrastructure such as transportation, energy and water are additional costs to the mining projects.

The aspect of production and growth in the coal and base metals require a well-developed and efficient infrastructure. Unavailability of trains to dispatch minerals to the domestic and international market has a great impact on production.

Costs and falling prices are additional challenges to growth in the mining industry. Efficient processes and transition between the state-owned power utility companies will contribute towards an increase in domestic production and growth. The domestic volumes will increase resulting in increased and maintained employment numbers.

There is a decline in reserves in several coal mines due to their life span, depth and depleted resources. Significant investment will be required to replace those mines and keep supplies to the domestic and international market. The biggest challenges of production are high electricity and labour costs that are above inflation. This will erode any profit that can be used to grow the companies, benefit communities, and contribute towards the growth of the economy. Coal is a strategic resource which is important for the energy mix to address the electricity problems in the country.

An increase in production and growth in the mining operations can be achieved through promotion of mining and specific minerals, both nationally and internationally. Promotion of mining increases the demand for the minerals and their uses, which require increased supply, leading to high production.

Mineral commodities continue to experience a decline in investment, lower grades, increased mining depth, low production efficiencies, and effects of new technology. South Africa needs to work closely with original mining equipment manufacturers. Good producer and supplier relations are therefore required. Promoting the industrial and manufacturing uses of minerals will increase production. Technology and innovation initiatives will require upskilling of employees to ensure viability of modernised mining.

4.3.3.4. Resources and reserves

The fourth stage is defining the total mineral resources and reserves available in the country. It refers to aspects of updating the database and record keeping of the mineral data, life of the mine, and availability of the minerals after considering the evaluation, classification and depletion (see Figure 4.5). There are several SAMCODES (South African mineral reporting codes) which govern the reporting and evaluation of mineral resources and reserves. These codes, namely, SAMREC (South African code for the reporting of mineral exploration results, mineral resources and reserves) and SAMVAL (South African code for the reporting of mineral asset valuation) including other affiliated standards and codes of best practice are important in the evaluation and defining of total mineral resources and reserves. SAMCODES are internationally aligned and recognised by several international bodies and other mineral evaluation committees. Relevant institutions responsible for the resources and reserves are DMRE and CGS, with the assistance from MCSA utilising SAMCODES.

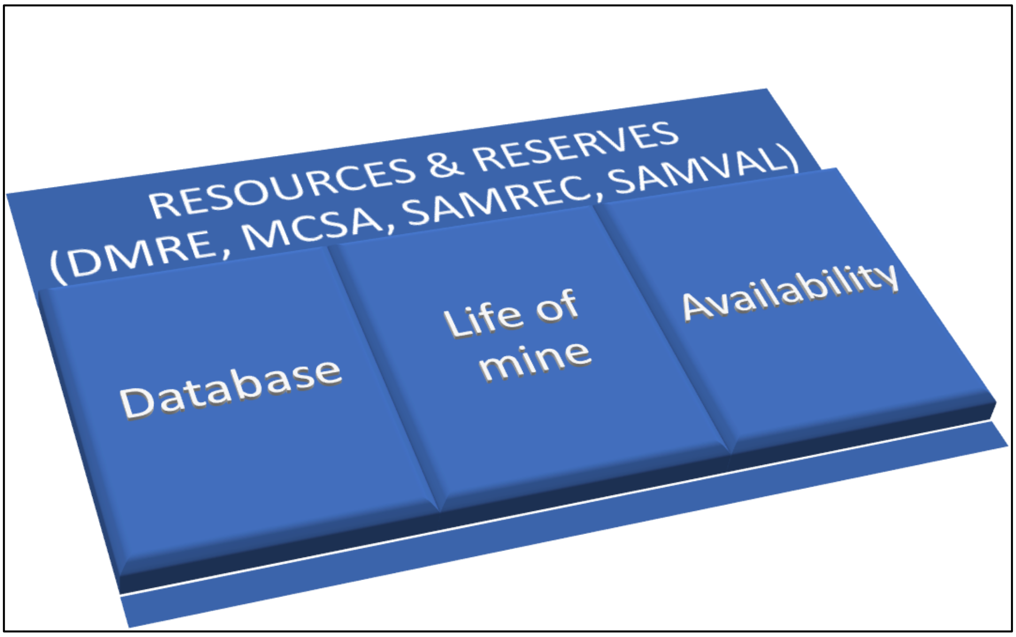


Figure 4.5: Resources and reserves in the classification of strategic and critical minerals

4.3.3.5. Marketing and demand

The fifth stage is the marketing of strategic and critical minerals to ensure that there is demand both locally and globally which will increase the importance of use of these minerals. Important aspects at this stage are risks and impacts, sales and production figures, market development to ensure supply, investment, market share and internal and external reliance, key technologies, industrial and manufacturing sectors, and economical significance (see Figure 4.6). Relevant institutions capable of and responsible for the implementation of the process are DMRE, National Treasury, MCSA and StatsSA.

The stakeholders in the country should promote and create a good environment for mining, while domestic utilisation and international need will create demand for minerals at a global scale. The promotion should grow other sectors of demand such as the investment sector, industrial sector and manufacturing sector.

Minerals are affected globally by the demand, supply and dynamics of the market. The demand is driven by factors such as population trends, economic growth, consumer choices, government policies, prices and technology. The supply is driven by factors such as resource endowment, market concentration, availability of capital, government intervention, expertise and equipment, changing technology, customer needs and importance of use, proximity to the market, logistics, and infrastructure. Market dynamics are affected by factors such as market concentration and transparency, barriers to entry, capital, knowledge, time, regulatory requirements, and labour.

These factors on demand, supply and market continue to affect the South African minerals industry. Marketing and demand aspects can be addressed and utilised to resolve the challenges experienced. Practical application of promoting and creating the demand for minerals using the aspects of stage five is applied below to platinum and coal as examples but can be applied to other strategic and critical minerals.

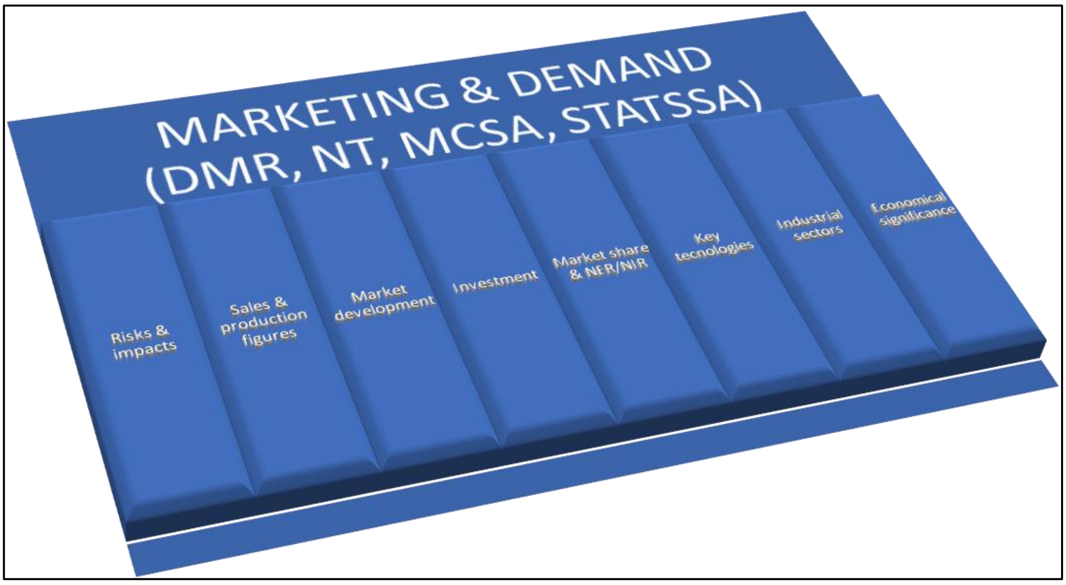


Figure 4.6: Marketing and demand in the classification of strategic and critical minerals.

A risk of global oversupply of minerals such as thermal coal and other materials will lead to depressed markets and subsequent reduced prices. Technological and environmental changes can impact the demand of a mineral. It is evident from consumption and production figures that coal demand in Asian markets is still strong, while North America and Europe are moving towards cheaper and cleaner natural gas and renewables such as wind and solar.

China continues to create demand for coal and has approved 141 million tonnes of new yearly coal capacity in 2019 compared to 25 million tonnes in 2018. Coal is experiencing challenges from financial institutions and internationally listed companies, which will affect investment and demand. The abundance of coal in South Africa places the country in a good position to use its competitive advantage and cost-effectiveness to develop the economy towards addressing the socio-economic divide between South Africa and the developed countries.

In South Africa, climate change has resulted in a few challenges. Coal producers can also focus on supplying the domestic market and promoting clean-coal technology towards creating an export market. This can be done by exploring options for more efficient combustion of coal with reduced emissions of sulphur dioxide and nitrogen oxide such as fluidized-bed combustion, carbon capture storage, coal liquefaction and gasification. The export market is still available and will require a demand for coal and other materials.

South Africa is the largest producer of platinum and rhodium, and the second largest producer of palladium. The main uses and applications such as hard-disk drives, capacitors, flat-panel displays, autocatalysts, fuel cells, automotive components continue to make PGM's strategic and critical. Reduced or lack of supply of these minerals will have a great impact globally for the economy and technological development. The industry is experiencing problems due to changes in global supply and demand, such as an increase in the recycling industry, low production from local mines, low demand, lower prices, and high costs of labour and electricity. Changes in global supply have greater impact in the criticality of these minerals. All these factors affected the market and demand. There are also threats of substitution from catalytic uses by battery electric cars. This will be the case when at least 60% of the cars are electric. In addition, PGMs have lost its market share and there is currently limited market development.

In order to grow the market, the country requires strong leadership and focused investment in market development. In addition, a future market for the strategic and critical minerals which can be achieved through clear strategies, funding and partnerships, should be developed by working with governments and investors. The status granted to gold can be created for platinum as a drive for investment by promoting a platinum coin similar to the way a gold coin can create a market demand.

The country should focus on promoting and investing in the importance of use for platinum in jewellery. This will create a market for the platinum group metals which includes the use of fuel cell and hydrogen technology in the industrial and manufacturing sectors.

4.3.3.6. Subject Matter Expert (SME) Team

The sixth stage in the classification of strategic and critical minerals towards developing a framework is the formation of a team and involvement of subject matter experts. Aspects to be considered at this stage are research and verification; upstream and downstream processes of processing, beneficiation and industrialisation; location and concentration of economic mineral deposits; relevant and suitable technology to be applied; aspects of recycling; reviewing of policies and promotion of mining; a drive for importance of use by researching on the future use of minerals; addressing the supply; and creating demand for the strategic and critical minerals (see Figure 4.7). Relevant stakeholders responsible for the implementation are the Department of Science and Technology (DST), consultants from different disciplines, MCSA, users (producers, suppliers and consumers), and specialised academics.

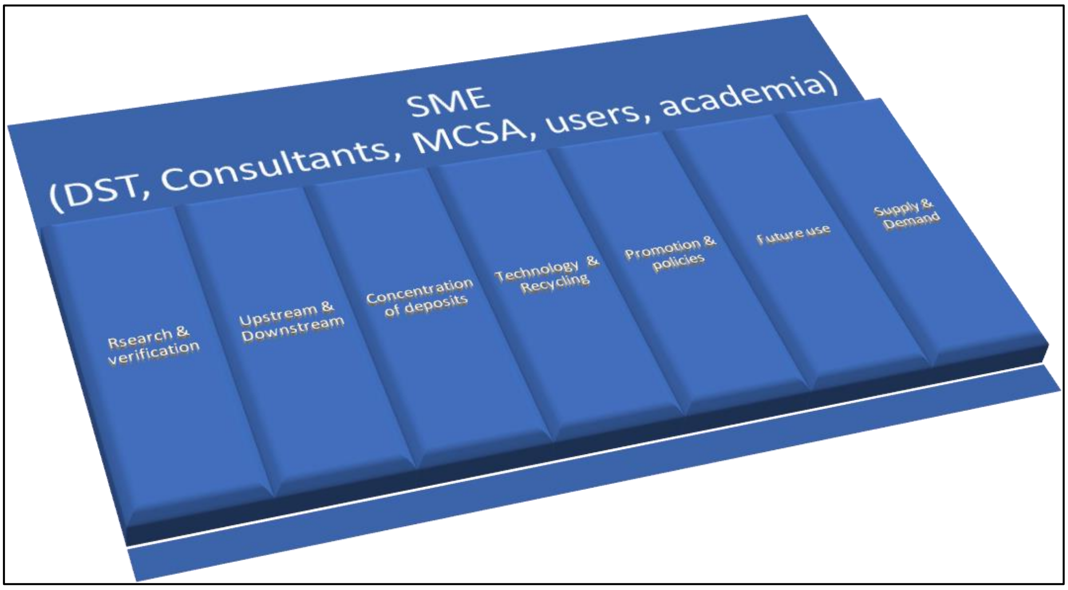


Figure 4.7: Subject matter experts in the classification of strategic and critical minerals

The mining industry is well established in the country. It has also developed expertise on deep underground mining. Further, the skills, training and knowledge acquired should be utilised to improve the industry. In addition, the private sector expertise should be used to grow the mining sector and implement new technology. Lessons may be learnt in the way the mining sector functions now via the stock market.

4.3.3.7. Investment

The seventh stage in the classification of strategic and critical minerals is investment. Mining will be affected by profits (shareholders), people (communities) and the planet (environment) where they need to ensure sustainability of the industry. Aspects of the investment stage are profits and income, economic benefits and equal distribution, corporate social responsibility, and sustainability of the industry (see Figure 4.8). The relevant capable and responsible stakeholders for the implementation of the process are investors, government, communities and mining companies.

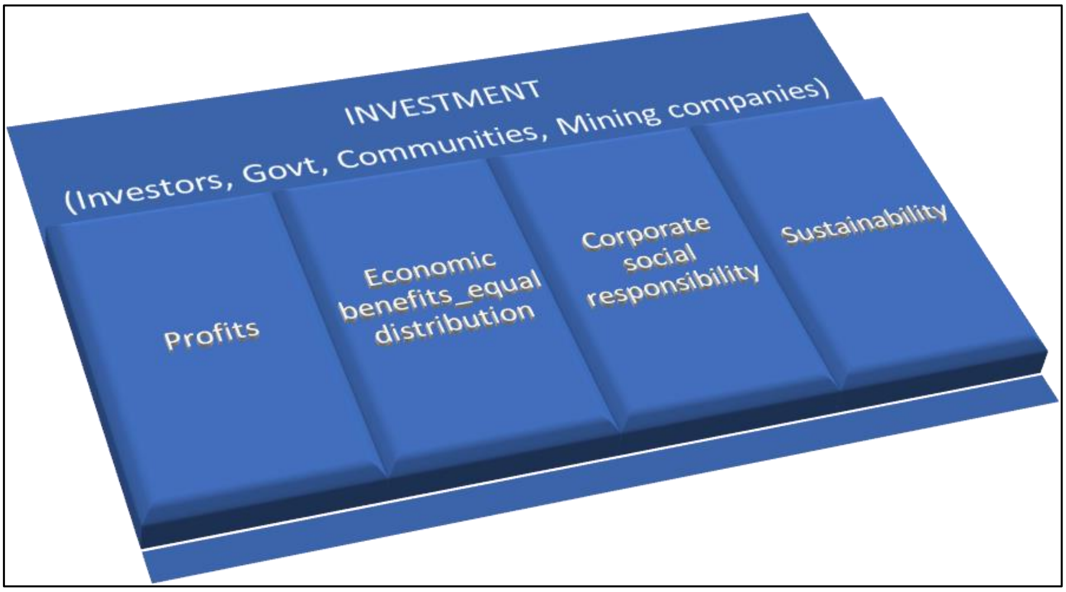


Figure 4.8: Investment and income in the classification of strategic and critical minerals

Income and profits from mining should benefit the country and its citizens. Corporates should be socially and environmentally responsible in the communities where they operate. It is important to identify main development potentials that can attract and promote investments, including environmental sustainability.

South Africa faces several challenges which can be resolved to some extent by investment. Challenges experienced include weak economic growth, low or stagnant investment, low confidence from investors in the business sector, high rate of unemployment, government fiscal deficits, high debt levels and corruption, as well as poor performance from state-owned enterprises.

A venture capital fund can be used to promote and create demand for strategic and critical minerals, locally and internationally. Capital investment is required to promote exploration and development of strategic and critical minerals. Criticality of these minerals will ensure a high demand for them.

Investment in technological innovations to conduct research and development in different mineral sectors can result in new expertise which can promote supply by lowering costs, increasing efficiencies, and improving environmental performance.

4.4. Chapter summary

Communities living in the vicinity of mining operations should be considered to understand the socio-economic impacts of mining. The aspect of whether a mineral is critical and strategic from the perspective of a community is better assessed from community inputs.

Respondents' perceptions about the socio-economic impact differed slightly from one community to another, depending on whether it is in a rural or urban area. The questions in the survey are related to the community, environment, economic activities, and settlement and mining operations in the local area of the respondents. It was conducted in this manner to establish the socio-economic impacts and benefits as perceived and experienced by the communities in the local mining areas.

Positive impacts are mostly noted from employment benefits, where majority of community members are employed by mines, receiving a salary and each household has two to five members. The negative impacts were mostly observed in the social and health status of the community. Many social ills such as increased population, crime, drugs, teenage pregnancy, failing infrastructure and poor service delivery were experienced in the community. Participation and perceptions of communities regarding the contribution of minerals that are strategic and critical are necessary in the screening and selection of minerals.

Minerals that are critical and strategic are screened according to the fifteen parameters identified in the study. These parameters are relevant to the South African context and mining industry. After the screening process, identified minerals are assessed through the seven stages of mineral evaluation to classify them as strategic and critical. In the stages, responsible departments or personnel are identified with associated roles and responsibilities to evaluate a mineral.

This will result in a list of potential strategic and critical minerals in the framework. The classification of these potential minerals is divided into three sections, that is, socio-economic impacts, risk and economic importance. In the next chapter, an analytical framework is developed to assess the socio-economic impact of the strategic and critical minerals from community perspective regarding their contribution to their communities.

CHAPTER 5: ANALYTICAL FRAMEWORK FOR ASSESSING SOCIO-ECONOMIC IMPACTS

5.1. Introduction

Different aspects were noted from the previous studies regarding mining impacts and this study identified four main impacts that may influence the perceptions of local people in the vicinity of the mining operations. The local communities' perceptions of the socio-economic impacts of mining were assessed according to personal characteristics, employment and economic activities, community projects and environment and settlement (see Figure 5.1).

In the questionnaire, respondents were first asked to assess and indicate the level at which the different activities have positively or negatively impacted their local community because of the mining operations in their area. This was done through the use of a five-point Likert scale and by the indication of Yes or No for a status of the activity.

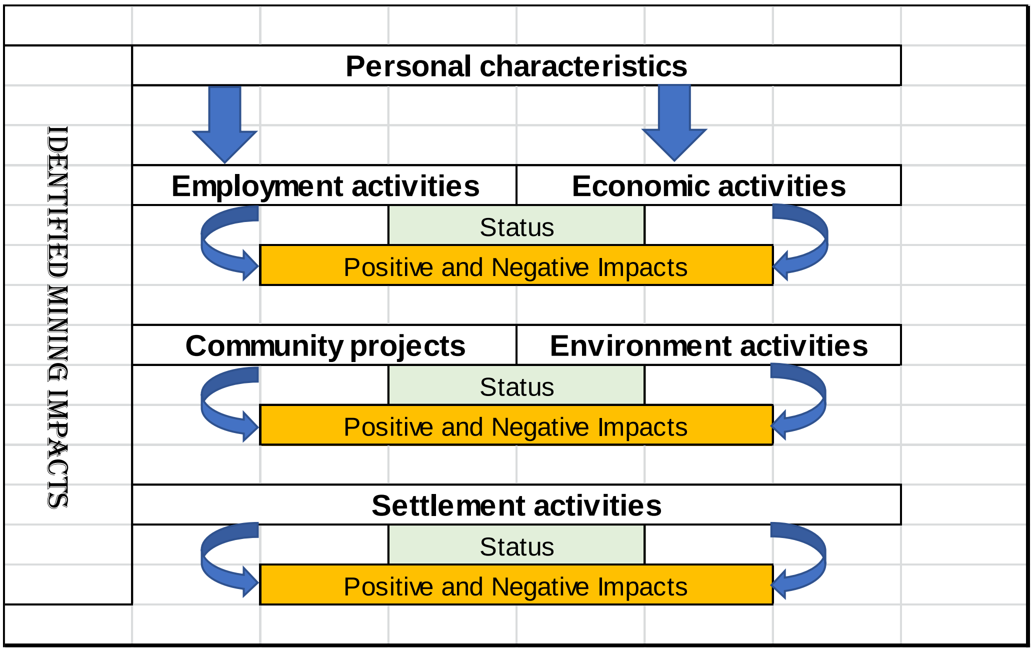


Figure 5.1: Analytical framework of this study (Source: Illustrated by the author)

Respondents were also asked to assess and indicate the level at which increased migration of labour, environmental conditions (management, minimisation, disposal, recycling and littering), water (quality, reduction, contamination and management), land availability (conflicts and occupation), high crime levels, abuse of drugs and alcohol, and teenage pregnancy have negatively impacted their local community because of the mining operations. Respondents also had an option to write other positive or negative impacts not addressed by the different questions.

Analysis is used to develop analytical framework which is contributing to the socio-economic impact aspect of the overall framework.

5.2. Perceived overall socio-economic benefits

This section assessed and analysed the local communities' perceptions of the overall socio-economic benefits according to the four identified impacts. The influence of the different impacts on their perception of the benefits is important in understanding the contribution of strategic and critical minerals. Different statistical techniques such as the independent sample t-test or analyses of variance were performed to test whether the means of subsamples significantly differ from each other ($p < 0.05$) (Table 5.1) are discussed. It was found that gender and educational level have no significant effects on the perceived benefits.

Table 5.1: Overall descriptive statistics of the employment and economic activities, projects and settlement factors

	N	Minimum	Maximum	Mean	Std. Deviation
a10 (Increased migration of labour)	690	1	5	3.72	1.120
d10 (Land availability)	690	1	5	3.52	1.166
e10 (High crime levels)	690	1	5	3.81	1.098
f10 (Abuse of drugs and alcohol)	690	1	5	4.16	1.039
g10 (Teenage pregnancy)	690	1	5	3.89	1.113
b12 (Educational facilities)	690	1	5	3.13	1.269
b13 (Community strikes & protests)	690	1	5	3.68	1.209
b14 (Years living in community)	690	1	5	3.51	0.723
a16 (Increased informal settlement)	690	1	5	3.79	1.192
b16 (Higher rental and house prices)	690	1	5	4.18	1.083
c16 (Increased population)	690	1	5	3.96	1.013
d16 (Inadequate infrastructure and poor services)	690	1	5	4.10	1.176

The abuse of drugs and alcohol, teenage pregnancy, high crime levels, increased migration of labour, and land availability with high means of 4.16, 3.89, 3.81, 3.72 and 3.52 respectively (see Table 5.1) are considered as the main aspects in the employment and economic activities factor that negatively impacted the community because of the mining operations in the area.

In the community projects and environment factor, the positive aspect considered by communities are the benefits of educational facilities due to mining operations in their area; however, the negative impact was the community strikes and protests.

Many participants are aware of the developments in the community as they have resided in the area for more than 11 years. The higher rental and house prices, inadequate infrastructure and poor services, increased population and increased informal settlement are considered as the main aspects in the settlement factor that negatively impacted the community because of the mining operations in the area.

Table 5.2: Overall descriptive statistics of the projects and settlement activities factors.

	N	Minimum	Maximum	Mean	Std. Deviation
c12 (Bursaries and scholarships)	690	1	5	1.95	1.191
c13 (Damaged houses)	690	1	5	1.80	1.187
a15 (Resettlement to better areas)	690	1	5	1.79	1.233
b15 (Compensation)	690	1	5	1.49	0.946
c15 (Schools)	690	1	5	2.91	1.263
d15 (Houses)	690	1	5	1.99	1.209

It is perceived that mining companies are not interested to grant bursaries and scholarships to the community. There were no major damages to the houses as most settlement was informal closer to the mines; therefore, no compensation for displacement was required. Mining companies did not assist with resettlement to better areas and no adequate schools were built in the community as a result of the mining operation in that community (Table 5.2).

5.3. Validity and reliability

Validity and reliability of data are important for accurate interpretation. Cronbach's alpha was used to obtain the reliability index of the data. Exploratory factor analysis has been used to determine validity of the instrument. Kaiser-Meyer-Olkin (KMO) test determines whether the sampling was adequate to proceed with factor analysis. If the KMO is greater than 0.6; then, the sampling is adequate (Chan and Idris, 2017).

5.3.1. Positive impacts of employment and economic activities

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.800

The value of KMO is 0.800 and indicates that the sampling conducted was adequate and factor analysis is useful for the data; the analysis will therefore yield distinct and reliable factors. It further indicates a strong correlation between indicators that are factor analysed. Two factors were extracted that explained 63.539% of the total variance.

Table 5.3: Total variance explained – positive impacts of employment and economic activities

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %	Rotation Sums of Squared Loadings[a] Total
1	2.871	47.849	47.849	2.871	47.849	47.849	2.523
2	0.941	15.690	63.539	0.941	15.690	63.539	2.055
3	0.708	11.794	75.332				
4	0.551	9.182	84.515				
5	0.477	7.947	92.462				
6	0.452	7.538	100.000				
Extraction Method: Principal Component Analysis.							

The pattern matrix is showing two constructs for the positive impacts of employment and economic activities, namely direct and indirect employment (see Table 5.3). Mining operations in the community have positive impacts and benefits as a result of direct employment with a high mean of 3.6319 and standard deviation of 0.87166. These benefits are realised through the training and skills offered by the mine to community members, creating more tradesmen in the community which brings about improved quality of life because of direct employment of local people.

Table 5.4: Pattern matrix – positive impacts of employment and economic activities

	Component: Direct Employment	Component: Indirect Employment
e9 (Training and skills)	0.922	
a9 (Improved quality of life)	0.782	
b9 (Direct employment)	0.581	0.290
d9 (More tradesmen)	0.553	
c9 (New business opportunities)		0.873
f9 (Indirect employment)		0.771
Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization.		

Mining also has indirect employment benefits in the community as a result of mining operations where the mean is 2.7674 with a standard deviation of 0.90829. However, these benefits and new business opportunities require high capital and expertise. Therefore, these opportunities are given to people and contracting companies outside the local community in the area of the mining operations. It is also perceived that employment from indirect mining-related companies has been offered to outsiders because the contracting companies normally bring their own employees.

Direct employment is more important to the local community compared to the indirect employment as it benefits the community from the mining operations (see Table 5.5).

Table 5.5: Descriptive statistics – positive impacts of employment and economic activities

	Cronbach Alpha	Min	Max	Mean	Std. Deviation
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	0.606	1.00	5.00	2.7674	0.90829
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	0.751	1.00	5.00	3.6319	0.87166

The reliability of the data is good at the Cronbach's Alpha of 0.751 for employment factors and 0.606 for indirect employment factors.

5.3.2. Negative impacts of employment and economic activities

The KMO for the negative impact factors of employment and economic activities is 0.6072. Three factors were extracted that explained 70.238% of the total variance (see Table 5.6).

Table 5.6: Total variance explained – negative impacts of employment and economic activities

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.470	35.280	35.280	2.470	35.280	35.280	2.275
2	1.523	21.761	57.041	1.523	21.761	57.041	1.605
3	0.924	13.196	70.238	0.924	13.196	70.238	1.469
4	0.731	10.449	80.687				
5	0.562	8.026	88.712				
6	0.403	5.758	94.471				
7	0.387	5.529	100.000				

The pattern matrix for the negative impacts of employment and economic activities shows three constructs, namely negative impacts on social issues (i.e., abuse of drugs, teenage pregnancy and high crime levels), negative impacts on environmental issues (i.e., water and environment) and negative impacts on land issues (i.e., increased migration of labour and land availability) See Table 5.7 below.

Table 5.7: Pattern matrix – negative impacts of employment and economic activities

	Component		
	Negative impacts on social issues	Negative impacts on Environment issues	Negative impacts on Land issues
f10 (Abuse of drugs and alcohol)	0.823		
g10 (Teenage pregnancy)	0.822		
e10 (High crime levels)	0.782		
c10 (Water)		0.899	
b10 (Environment)		0.854	
a10 (Increased migration of labour)			0.931
d10 (Land availability)	0.341		0.489

It is perceived that the abuse of drugs and alcohol, teenage pregnancy, and high crime levels are the aspects of high negative impacts of the mining operations in the community. In addition, increased migration of labour and lack of land availability in the community are due to the mines in the area. The local people do not see water quality, reduction, contamination, and poor management as resulting from the mines in their community including environmental conditions such as management, minimisation, disposal, recycling and littering as a major negative impact, a mean of 2.3493 and standard deviation of 1.09877 (see Table 5.8).

Table 5.8: Descriptive statistics – negative impacts of employment and economic activities

	Cronbach Alpha	Min	Max	Mean	Std. Deviation
Employment_negative_environmental (b10,c10) {Positive impacts on water and environ-conditions)	0.715	1.00	5.00	2.3493	1.09877
Employment_negative_soc_migration (a10,d10,e10,f10,g10) {Negativ impacts on social issues}	0.713	1.00	5.00	3.8198	0.75576

The negative impacts of employment and economic activities with regard to social issues such as increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy are high with a mean of 3.8198 and standard deviation of 0.75576 compared to water and environmental conditions (see Table 5.8).

The reliability of the data is good at the Cronbach's Alpha of 0.751 for employment negative environmental factors and 0.713 for employment negative social migration factors.

5.3.3. Positive and negative impacts of community projects and environment

The KMO factor of the positive and negative impacts of community projects and environment is 0.659. Three factors were extracted that explained 72.292% of the total variance (see Table 5.9).

Table 5.9: Total variance explained – positive and negative impacts of community projects and environment

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.376	33.948	33.948	2.376	33.948	33.948	2.129
2	1.705	24.356	58.304	1.705	24.356	58.304	1.984
3	0.979	13.988	72.292	0.979	13.988	72.292	1.073
4	0.623	8.901	81.193				
5	0.544	7.766	88.959				
6	0.467	6.668	95.627				
7	0.306	4.373	100.000				

The pattern matrix for the positive and negative impacts of community projects and environment shows three constructs, namely negative impacts on environment (i.e., damaged houses, pollution and labour/union strikes), positive impacts on community (i.e., improved health services, educational facilities, bursaries and scholarships) and negative impacts on community (i.e., community strikes or protests) (see Table 5.10).

Table 5.10: Pattern matrix – positive and negative impacts of community projects and environment

	Component		
	Negative impacts on Environment	Positive impacts on community	Negative impacts on community
c13 (Damaged houses)	0.842		
a13 (Pollution)	0.737		
d13 (Labour/ Union strike)	0.733		
a12 (Improved health services)		0.899	
b12 (Educational facilities)		0.884	
c12 (Bursaries and scholarships)	0.471	0.564	-0.301
b13 (Community strikes or protests)			0.906

Mining companies have moved most of their employees out of the hostels and built houses to provide better housing and accommodation to employees. However, according to the study, the communities and employees are not fully aware of this. Some of the housing projects take longer to be completed and handed over to the rightful owners. Other people (illegitimate owners) therefore tend to hijack and occupy the houses.

The bursaries and scholarships are not awarded to communities as it happened years ago. It is perceived that these limited bursaries and scholarships are in the hands of the wrong community leaders who award and allocate the bursaries to their families, relatives and friends.

There is also a perception that mine management is using the bursaries and scholarships to gain the trust and support of community leaders. It is indicative of a low mean of 2.6150 and standard deviation of 0.98074 (see Table 5.11).

The negative impact of community strikes or protests on the community as a result of the mining operations in the area is high with a mean of 3.6807 and standard deviation of 1.21027. Communities experience service delivery protests and perceived lack of employment of locals by mines.

Table 5.11: Descriptive statistics – positive and negative impacts of community projects and environment

	Cronbach Alpha	Min	Max	Mean	Std. Deviation
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	0.721	1.00	5.00	2.6150	0.98074
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	0.699	1.00	5.00	2.4454	0.94332
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}		1.00	5.00	3.6807	1.21027

The reliability of the data is good at the Cronbach's Alpha of 0.721 for environmental positive factors and 0.699 for environmental negatives of mine factors (see Table 5.11).

5.3.4. Positive and negative impacts of settlement

The KMO value of the positive and negative impacts of settlement is 0.697. Three factors were extracted that explained 69.356% of the total variance (see Table 5.12).

Table 5.12: Total variance explained – positive and negative impacts of settlement

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	2.793	34.917	34.917	2.793	34.917	34.917	2.329
2	1.730	21.620	56.536	1.730	21.620	56.536	2.319
3	1.026	12.820	69.356	1.026	12.820	69.356	1.207
4	0.746	9.322	78.679				
5	0.523	6.540	85.219				
6	0.493	6.161	91.379				
7	0.414	5.171	96.550				
8	0.276	3.450	100.000				
Extraction Method: Principal Component Analysis.							

The pattern matrix for the positive and negative impacts of settlement shows three constructs, namely negative impacts on settlement (i.e., inadequate infrastructure and poor services, increased informal settlement, increased population, higher rental and house prices), positive impacts on settlement (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses have been built) and positive impacts on schools (i.e., adequate schools have been built) (see Table 5.13).

Table 5.13: Pattern matrix– positive and negative impacts of settlement

	Component		
	Negative impacts on Settlement	Positive impacts on Settlement	Positive impacts on schools
d16 (Inadequate infrastructure and poor services)	0.777		
a16 (Increased informal settlement)	0.759		
c16 (Increased population)	0.753		

b16 (Higher rental and house prices)	0.622		-0.395
a15 (Resettlement to better areas)		0.905	
b15 (Adequate compensation for displacement)		0.826	
d15 (Adequate houses have been built)		0.708	-0.362
c15 (Adequate schools have been built)			-0.916

Local people have a high perception of the negative impacts of mining operations in the community due to inadequate infrastructure and poor services, increased informal settlement, increased population, and higher rental and house prices with a mean of 4.0059 and standard deviation of 0.83530 (see Table 5.14). It is expected that mines will bring positive development to the community. However, local people are not aware of resettlement in better areas, adequate compensation for displacement, and adequate houses that have been built by the mines in their area. Some people are aware of some of the schools that have been built, renovated or donated by the mines to the community.

The Cronbach's Alpha co-efficient (> 0.7) is good and within the minimum acceptable value of internal consistency indicating a good reliability on the data collected and analysed.

Table 5.14: Descriptive statistics – positive and negative impacts of settlement

	Cronbach Alpha	Minimum	Maximum	Mean	Std. Deviation
Settlement_positive_housing a15, b15, d15) {Positive impacts on relocation, compensation, housing}	0.782	1.00	5.00	1.7575	0.94884
Settlement_positive_schools (c15) {Positive impacts on schools built}	N/A	1.00	5.00	2.9087	1.26310
Settlement_negative (a16, b16, c16, d16) {Positive impacts on informal settlement, rental prices, population, infrastructure)	0.736	1.00	5.00	4.0059	0.83530

The reliability of the data is good at the Cronbach's Alpha of 0.782 for settlement positives of housing factors and 0.736 for settlement negatives factors (see Table 5.14).

5.4. The effect of biographical data on factors for the positive and negative impacts in the analytical framework

The biographical data of the sample (namely, personal characteristics) is analysed according to their variances, tested and compared to the aspects of the positive and negative impacts of mining in the framework. Identified aspects of the mining impacts in the framework are employment and economic activities, community projects and environment, and settlement. In the discussions correlations are analysed among younger people (21 – 40 years), older people (41 years and more), lower education level (lower than grade 7), higher level (higher than grade 9), more people and dependents (3 and higher), less number (1 person), less years of employment (1 – 4 years), more years of employment (5 – 10 years), higher position (supervisor to manager), lower position (unskilled employees), shorter period living in the community (less than 4 years), longer period (more than 11 years).

5.4.1. Correlation of biographical ordinal variables with factors for the positive and negative impacts in the analytical framework

The identified positive and negative mining impacts in the framework for employment and economic activities, community projects and environment, and settlement with their related aspects are compared to the personal characteristics, namely age, education level, household members and dependants, number of years in the employment, position at work and numbers of years residing in the community. These aspects were analysed and correlated with the level of change in one variable due to the change in the other.

A minor (0.166) or no correlation (0.00) is observed between age, education level, number of household members and dependants, and indirect employment-related aspects of the mining operations in the local community (see Table 5.15).

Table 5.15: Correlation coefficient between indirect employment – positive impacts of employment and economic activities – and biographical data

	Employment_business (c9, f9) {Indirect employment: Positive impacts employment}
Age	0.00
Education (level)	0.01
Household (number)	0.021
b8 (years employed)	.115**
d8 (Position at work)	.166**
b14 (Years in the community)	-.075*
**. Correlation is significant at the 0.01 level (2-tailed)	
*. Correlation is significant at the 0.05 level (2-tailed)	

There is a positive correlation between the indirect employment aspects (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) and numbers of years employed (r = 0.115) and position at work (r = 0.166) (see Table 5.15). The people who were employed for a short period (less than four years) indicated lower positive impacts or benefits of indirect employment in the community as opposed to those who were employed for a longer period. Similarly, employees at a lower position at work (below supervisory role) indicated lower positive impacts of indirect employment aspects in the community, while those at a higher position (supervisory role) at work show higher positive impacts or benefits of new business opportunities and increased employment as a result of the mines in their community. Most participants are employees; therefore, companies offering indirect employment mostly come with their own supervisors. Indirect employment is mostly contracting work and does not offer many years of employment.

There is a negative correlation between the indirect employment aspects (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) and number of years of staying in the community (r = -0.075) (Table 5.15). The people who lived in the community for a shorter period or only a few years (less than four years) indicated higher positive impacts or benefits of the indirect employment aspects in their area as a result of the mining operation. Those who lived longer (more than eleven years) in the community indicated a lower positive impact or benefits of indirect employment. There is a perception that indirect employers such as mine contracting companies tend to employ mostly people outside the community.

The age (r = 0.173), years employed (r = 0.201), position at work (r = 0.177) and years in the community (r = 0.162) have a positive correlation to direct employment aspects (i.e., improved quality of life, increased employment, more tradesmen, and training and improvement of skills) (see Table 5.16). Older people (more than 50 years), employees who have been employed for longer or many years, employees in a higher position at work, and people who stayed longer in the community, have indicated higher positive impacts and benefits of direct employment aspects from the mining operations. Younger people (less than 30 years), employees that have been employed for a shorter period, employees in a lower position at work and people who stayed for a shorter period in the community have indicated lower positive impacts and benefits of direct employment aspects. It is perceived that mining companies consider employees' age, experience, skills and number of years in the community to hire and determine positions at work, which is a disadvantage to employees.

Table 5.16: Correlation coefficient between direct employment – positive impacts of employment and economic activities

	Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}
Age	.173**
Education (level)	-.115**
Household (number)	0.008
b8 (years employed)	.201**
d8 (Position at work)	.177**
b14 (Years in the community)	.162**
**. Correlation is significant at the 0.01 level (2-tailed)	
*. Correlation is significant at the 0.05 level (2-tailed)	

Education level (r = -0.115) has a negative correlation (i.e., negative relationship) to direct employment aspects (i.e., improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills) (see Table 5). People with a higher education level (tertiary level) indicated lower positive impacts and benefits from direct employment aspects in the community from mining operations. It is perceived that mining companies mostly employ unskilled workers, experienced employees and a few educated and specialised employees, which does not favour those with a higher education level from the local community. People believe that most of the educated people do not work in their local community. Community members with a lower education level (below grade 12) have indicated higher positive impacts and benefits from direct employment aspects of the mines in their area.

Table 5.17: Correlation coefficient between environmental conditions and water – negative impacts of employment and economic activities – and biographical data

	Employment_negative_environmental (b10, c10) {Negative impacts on water and environ-conditions)
Age	-.162**
Education (level)	0.06
Household (number)	.102**
b8 (years employed)	-.181**
d8 (Position at work)	-.167**
b14 (Years in the community)	-.136**
**. Correlation is significant at the 0.01 level (2-tailed) *. Correlation is significant at the 0.05 level (2-tailed)	

There is a negative correlation between environmental conditions and water aspects (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) and age (r = -0.162), number of years employed (r = -0.181), position at work (r = -0.167) and number of years in the community (r = -0.136) (see Table 5.17). Older people, employees who have been employed for a longer period or more years, employees at a higher position at work and people who have stayed for a longer period or many years in the community, have indicated low negative impacts of the environmental conditions (management, minimisation, disposal, recycling, and littering) and water (quality, reduction, contamination, and management) in the community as a result of the mining operations.

The younger people (adults younger than 30 years old), employees with a smaller number of years in employment (less than 3 years), employees in a lower position (below supervisory role) at work and people who have lived for few years in the community, indicated higher negative impacts of the environmental conditions.

There is a positive correlation between environmental conditions and water aspects and number of people in the household (r = 0.102) (see

Table 5.17). The households with more members in the family have indicated higher negative impacts of number of the environmental conditions.

There is a positive correlation between employment negative social migration issues (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) and the number of years living in the community (r = 0.196) (see Table 5.18).

Table 5.18: Correlation coefficient between social issues – negative impacts of employment and economic activities – and biographical data

	Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}
Age	0.05
Education (level)	-0.07
Household (number)	-0.015
b8 (years employed)	-0.068
d8 (Position at work)	-.087*
b14 (Years in the community)	.196**
**. Correlation is significant at the 0.01 level (2-tailed) *. Correlation is significant at the 0.05 level (2-tailed)	

The people who lived for longer years in the community have indicated higher negative impacts of social issues, such as increased migration of labour, land availability (conflicts and occupation), high crime levels, abuse of drugs and alcohol, and teenage pregnancy in their community as a result of mining operations in their area. Participants who have resided in the community for many years are affected by the social issues, especially increased migration of labour as a result of mines in the local community.

It is perceived that migrants are mostly renting accommodation and staying in the informal settlements and are likely to go back to their respective homes or countries of origin at the end of their employment or when the mine closes. Community members who lived for a shorter period in the community indicated lower negative impacts of social issues on their community.

A negative correlation is noted between employment negative social migration aspects and position at work (r = -0.087) (see Table 5.18). People who were in a lower position at work have indicated higher negative impacts of social issues in their community. It is perceived that people with a low income are vulnerable to abuse of drugs and alcohol, high crime levels, and teenage pregnancy in the community. The people who were employed for many years and in a higher position at work indicated lower impacts of social issues.

Table 5.19: Correlation coefficient between community projects – positive impacts of community projects – and biographical data

	Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}
Age	-.097*
Education (level)	.091*
Household (number)	0.015
b8 (years employed)	0.008
d8 (Position at work)	0.057
b14 (Years in the community)	0.018

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

There is a negative correlation between environmental positives (i.e., improved health services, educational facilities, bursaries and scholarships) and age (r = -0.097) (see Table 5.19).

The older people have indicated lower positive impacts or benefits with regard to improved health services, educational facilities, bursaries and scholarships in their community as a result of mines in their area. They believe that the mines have stopped offering bursaries, scholarships, facilities and services that they used to give to the community in the past.

Younger people indicated higher positive impacts of community projects in their area as a result of mining operations.

There is a positive correlation between environmental positives (i.e., improved health services, educational facilities, bursaries and scholarships) and education level (r = 0.091) (see Table 5.19). The people with a higher education level have indicated higher positive impacts or benefits with regard to improved health services, educational facilities, bursaries and scholarships in their community as a result of mines in their area. The less educated people indicated lower positive impacts of community projects in their area as a result of mining operations. These respondents are not familiar with processes related to infrastructure development and roles of the municipality in community projects.

Table 5.20: Correlation coefficient between environment and community – negative impacts on community projects and environment – and biographical data

	Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)
Age	-0.07
Education (level)	0.05
Household (number)	.081*
b8 (years employed)	-0.067
d8 (Position at work)	-0.037
b14 (Years in the community)	-.103**
**. Correlation is significant at the 0.01 level (2-tailed)	
*. Correlation is significant at the 0.05 level (2-tailed)	

There is a negative correlation between environmental negatives of the mine (i.e., pollution, damaged houses, and impact of labour strikes on work function) and years in the community (r = -0.103) (see Table 5.20). People who have been employed for many years and those who lived in the community for many years have indicated lower negative impacts of pollution (dust, noise, waste, and water), damaged houses, and labour strikes on work function in the community as a result of the mines in their area. The people who lived in the community for a few years have indicated higher negative impacts of pollution, damaged houses and impact of labour strikes on work function in the community. Pollution and labour strikes as a result of the mining operations is a cause for concern.

There is a positive correlation between environmental negatives of the mine (i.e., pollution, damaged houses, and impact of labour strikes on work function) and the total number of household members and dependants (r = 0.081) (see Table 5.20). The households with more people and dependants in the family have indicated higher negative impacts of dust, noise, waste and water pollution, damaged houses and impact of labour strikes on work function in the community as a result of the mines. Households with fewer people and dependants indicated lower negative impacts of environmental and community effects in the community.

Table 5.21: Correlation coefficient between community strikes or protests – negative impacts on community – and biographical data

	Environmental_negative_community (b13) {Negative impacts on environment: community strikes}
Age	0.05
Education (level)	-0.06
Household (number)	0.051
b8 (years employed)	-0.017
d8 (Position at work)	0.049
b14 (Years in the community)	.283**
**. Correlation is significant at the 0.01 level (2-tailed)	
*. Correlation is significant at the 0.05 level (2-tailed)	

There is a positive correlation between environmental negatives in the community (i.e., community strikes or protests) and years of living in the community (r = 0.283) (see Table 5.21). People who stayed in the community for many years have indicated higher negative impacts of community strikes and protests. The people who stayed for a few years in the community have indicated lower negative impacts of community strikes and impacts. Local people that lived in the community for many years experienced more negative impacts of community protests compared to the newcomers. The community protests are a concern to the local people as a result of their perceived expectations from the mining companies.

There is a negative correlation between settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) and age (r = -0.180), number of years employed (r = -0.086) and number of years residing in the community (r = -0.148) (see Table 5.22).

Older people, employees who have been employed for many years, and people who have lived in the community for many years have indicated lower positive impacts or benefits of resettlement to better areas by the mines, adequate compensation for displacement from the mines, and adequate houses built by the mines in their community. These respondents have stayed longer in the community and have seen slow pace of developments in their area.

Table 5.22: Correlation coefficient between housing – positive impacts on settlement – and biographical data

	Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}
Age	-.180**
Education (level)	.117**
Household (number)	0.033
b8 (years employed)	-.086*
d8 (Position at work)	0.014
b14 (Years in the community)	-.148**
**. Correlation is significant at the 0.01 level (2-tailed)	
*. Correlation is significant at the 0.05 level (2-tailed)	

Younger people, employees who have been employed for few years and people who have lived in the community for a few years have indicated higher positive benefits of relocation, compensation and housing in the community as a result of mining operations in their area. This is the case because mining companies started to build and contribute towards housing for their employees.

There is a positive correlation between settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) and the education level (r = 0.117) (see Table 5.22).

Community members with higher education levels have indicated higher positive benefits of resettlement to better areas, adequate compensation for displacements, and adequate housing in their community as a result of mining operations. Mining companies mostly provide accommodation or housing allowances for professionals and skilled employees. People with lower education levels have indicated lower positive benefits of housing, relocation and compensation from the mines.

There is a positive correlation between settlement positives of schools (i.e., adequate schools built) and age (r = 0.087), number of years employed (r = 0.089), and number of years in the community (r = 0.120) (see Table 5.23). Older people, employees who have been employed for many years, and people who lived in the community for many years have indicated higher positive impacts and benefits of adequate schools that have been built by the mining companies in their community. Younger people, employees who have been employed for fewer years and people who lived in the community for fewer years have indicated lower positive impacts and benefits of adequate schools built in their community as a result of mines in their area. Mining companies over time have built or contributed towards the development of schools in the community.

Table 5.23: Correlation coefficient between adequate schools built – positive impacts on settlement– and biographical data

	Settlement_positive_schools (c15) {Positive impacts on schools built}
Age	.087*
Education (level)	-0.01
Household (number)	0.021
b8 (years employed)	.089*
d8 (Position at work)	0.057
b14 (Years in the community)	.120**
**. Correlation is significant at the 0.01 level (2-tailed)	
*. Correlation is significant at the 0.05 level (2-tailed)	

There is a positive correlation between settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) and age (r = 0.182), and number of years living in the community (r = 0.185) (see Table 5.24). Older people and community members who lived in the community for many years indicated higher negative impacts of increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services in their community as a result of mining operations in their area. Younger people and community members who lived in the community for fewer years indicated lower negative impacts of informal settlement, prices, population, and service delivery as a result of mines in their community.

Table 5.24: Correlation coefficient between informal settlement, population and service delivery – negative impacts on settlement – and biographical data

	Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)
Age	.182**
Education (level)	-0.05

Household (number)	-.078*
b8 (years employed)	0.051
d8 (Position at work)	0.049
b14 (Years in the community)	.185**
**. Correlation is significant at the 0.01 level (2-tailed) *. Correlation is significant at the 0.05 level (2-tailed)	

The changes in the community due to inadequate infrastructure and increase of the informal settlement observed by older people are concerns that are ignored by the younger people. The younger people are used to the lifestyle in the community and do not compare to any past experiences.

5.4.2. Comparison of different aspects of the framework with positive and negative impacts according to t-Test

Statistical significance does not always mean that the result is important in practice when it shows small p-values, as it can yield smaller values as the sizes of the data sets increase, while the effect size of a sample is independent of sample size and is a good measure of practical significance. Practical significance indicates that the difference between means is a large enough difference to have an effect in practice (Ellis et al., 2003).

The biographical data of gender is compared to the positive impacts of direct and indirect employment, positive impacts on community environment projects, negative impacts on environment, positive impacts on housing and schooling settlement, and negative impacts on settlement related to informal settlement, property prices, population, and infrastructure.

The effect size for the negative impacts of mining operations on environmental conditions (i.e., management, minimisation, disposal, recycling, and littering) and water (i.e., quality, reduction, contamination, and management) is 0.47 (see Table 5.25), showing that the females (i.e.

mean = 2.74) indicated that the negative impacts of environmental conditions and water issues on the community are higher, compared to males (i.e. mean = 2.20) as a result of the mines.

The effect size for the positive impacts of settlement positives of housing is 0.41 (see Table 5.25). The females (mean =2.07) indicated that the positive impacts of resettlement to better areas by the mines, adequate compensation for displacement from the mines, and adequate houses built by the mines in their community are higher compared to males (mean = 1.64) as a result of the mining operations in their area.

It is perceived that mostly males migrate to the local community for employment in the mines. There is a strong perception about lack of better housing and schools built in the community by the mines.

Table 5.25: Different aspects of the framework compared to biographical data of gender according to t-Test – Group statistics

	Gender	N	Mean	Std. Deviation	p-value	Effect sizes
Employment_bussiness (c9, f9) {Indirect employment: Positive impacts employment}	Male	504	2.76	0.86	0.919	0.01
	Female	186	2.77	1.03		
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	Male	504	3.71	0.82	0.001	0.29
	Female	186	3.43	0.96		
Employment_negative_environmental (b10, c10) {Negative impacts on water and environmental conditions))	Male	504	2.20	1.04	0.000	0.47
	Female	186	2.74	1.15		
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Male	504	3.83	0.71	0.446	0.06
	Female	186	3.78	0.88		
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Male	504	2.57	0.97	0.033	0.18
	Female	186	2.75	1.00		
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Male	504	2.38	0.92	0.004	0.25
	Female	186	2.62	0.97		
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Male	504	3.65	1.21	0.345	0.08
	Female	186	3.75	1.20		
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Male	504	1.64	0.88	0.000	0.41
	Female	186	2.07	1.06		
Settlement_positive_schools (c15) {Positive impacts on schools built}	Male	504	2.95	1.23	0.170	0.12
	Female	186	2.80	1.34		
Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)	Male	504	4.10	0.76	0.000	0.34
	Female	186	3.76	0.98		

The effect size for the negative impacts of employment negatives on the environment (i.e., environmental conditions and water) is 0.41 (see Table 5.26). People who responded with a Yes (mean = 2.78) indicated that the negative impacts of environmental conditions (i.e., management, minimisation, disposal, recycling, and littering) and water (i.e., quality, reduction, contamination, and management) on their community are higher, compared to those who responded with a No (mean = 2.32).

The effect size for the positive impacts of environmental positive aspects (i.e., improved health services, educational facilities, bursaries and scholarships) is 0.39 (see Table 5.26). People who responded with a Yes (mean = 2.98) indicated that the positive impacts and benefits of improved health, educational facilities, bursaries and scholarships in their community are higher, compared to those who responded with a No (mean = 2.59).

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) is 1.14 (see Table 5.26). People who responded with a Yes (mean = 2.80) indicated that the positive impacts and benefits of resettlement to better areas, adequate compensation for displacement, and adequate houses built in their community are higher, compared to those who responded with a No (mean = 1.69).

The effect size for the negative impacts of settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) is 0.70 (see Table 5.26). People who responded with a Yes (mean = 3.41) indicated that the negative impacts on informal settlement, rental prices, population and service delivery in their community are lower, compared to those who responded with a No (mean = 4.04).

The local community people in the study are from towns, townships, rural and informal settlements. There is mostly no concern from respondents about the negative impacts of settlement related to increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services regarding the displacement of communities from where they used to live before because of the mines.

Table 5.26: Different aspects of the framework compared to displacement due to mining according to t-Test

c14 (displaced)		N	Mean	Std. Deviation	p-value	Effect sizes
Employment_business (c9, f9) {Indirect employment: positive impacts employment}	Yes	40	2.80	1.06	0.825	0.04
	No	649	2.76	0.90		
Employment_general_pos (a9, b9, d9, e9) {Direct employment: positive impacts employment}	Yes	40	3.40	1.03	0.142	0.24
	No	649	3.65	0.86		
Employment_negative_environmental (b10, c10) {Negative impacts on water and environ-conditions)	Yes	40	2.78	1.06	0.012	0.41
	No	649	2.32	1.10		
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Positive impacts on social issues}	Yes	40	3.63	0.77	0.105	0.27
	No	649	3.83	0.75		
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Yes	40	2.98	0.93	0.015	0.39
	No	649	2.59	0.98		
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Yes	40	2.70	1.02	0.109	0.27
	No	649	2.43	0.94		
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Yes	40	3.65	1.10	0.857	0.03
	No	649	3.68	1.22		
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Yes	40	2.80	0.97	0.000	1.14
	No	649	1.69	0.91		
Settlement_positive_schools (c15) {Positive impacts on schools built}	Yes	40	3.25	1.53	0.151	0.24
	No	649	2.89	1.24		
Settlement_negative (a16, b16, c16, d16) {Positive impacts on informal settlement, rental prices, population, infrastructure)	Yes	40	3.41	0.91	0.000	0.70
	No	649	4.04	0.82		

Most of the respondents were not displaced from their place of living, therefore they were not compensated.

The effect size for the negative impacts of employment negatives on environment (i.e., environmental conditions and water) is 0.37 (see Table 5.27). People who responded with a Yes (mean = 2.77) indicated that the negative impacts of environmental conditions (i.e., management, minimisation, disposal, recycling, and littering) and water (i.e., quality, reduction, contamination, and management) on their community are higher, compared to those who responded with a No (mean = 2.33).

The effect size for the positive impacts of environmental positive aspects (i.e., improved health services, educational facilities, bursaries and scholarships) is 0.54 (see Table 5.27). People who responded with a Yes (mean = 3.12) indicated that the positive impacts and benefits of improved health, educational facilities, bursaries and scholarships in their community are higher, compared to those who responded with a No (mean = 2.59).

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, adequate houses built) is 1.56 (see Table 5.27). People who responded with a Yes (mean = 3.12) indicated that the positive benefits of relocation, compensation and housing are higher, compared to those who responded with a No (mean = 1.70).

The effect size for the positive impacts of settlement positives of schools (i.e., adequate schools built) is 0.51 (see Table 5.27). People who responded with a Yes (mean = 3.57) indicated that the positive benefits of adequate schools built in their community are higher, compared to those who responded with a No (mean = 2.88).

The effect size for the negative impacts of settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) is 0.65 (see Table

5.27). People who responded with a Yes (mean = 3.49) indicated that the negative impacts on informal settlement, rental prices, population and service delivery in their community are lower, compared to those who responded with a No (mean = 4.03).

The majority (95.5%) responded with a No to the issue of compensation for relocation as a result of the mining operations to operate in the local community. They were less concerned about the compensation.

Table 5.27: Different aspects of the framework compared to compensation for displacement as a result of the mine according to t-Test.

d14 (compensation)		N	Mean	Std. Deviation	Std. Error Mean	Effect sizes
Employment_business (c9, f9) {Indirect employment: positive impacts employment}	Yes	28	2.98	1.00	0.18807	0.23
	No	659	2.75	0.90	0.03520	
Employment_general_pos (a9, b9, d9, e9) {Direct employment: negative impacts employment}	Yes	28	3.64	1.01	0.19091	0.01
	No	659	3.63	0.87	0.03377	
Employment_negative_environmental b10, c10) {Negative impacts on water and environ-conditions)	Yes	28	2.77	1.17	0.22195	0.37
	No	659	2.33	1.09	0.04265	
Employment_negative_soc_migratio (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Yes	28	3.69	0.82	0.15447	0.16
	No	659	3.82	0.75	0.02938	
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Yes	28	3.12	0.78	0.14670	0.54
	No	659	2.59	0.98	0.03830	
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Yes	28	2.75	0.99	0.18752	0.32
	No	659	2.43	0.94	0.03660	
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Yes	28	3.64	1.22	0.23125	0.03
	No	659	3.68	1.21	0.04711	
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Yes	28	3.12	0.78	0.14670	1.56
	No	659	1.70	0.91	0.03548	
Settlement_positive_schools (c15) {Positive impacts on schools built}	Yes	28	3.57	1.37	0.25937	0.51
	No	659	2.88	1.25	0.04881	
Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)	Yes	28	3.49	0.80	0.15077	0.65
	No	659	4,03	0.83	0.03237	

5.4.3. Comparison of different aspects of the framework with positive and negative impacts according to ANOVA

The different aspects of the framework, namely, geographical location of respondents, relationship of the respondent in the household, the household's main source of income, employment status and place of work of respondents, and their place of stay are compared. The comparison is conducted according to the analysis of the variances to the positive impacts of direct and indirect employment, community projects, housing and settlement including negative impacts on environment and settlement.

5.4.3.1. Different aspects of the framework compared to the geographical location

The geographical location of respondents is compared to the positive impacts of direct and indirect employment, positive impacts on community environment projects, negative impacts on environment, positive impacts on housing and settlement, and negative impacts on settlement related to informal settlement, property prices, population and infrastructure (see Table 5.28).

The response from Gauteng province is lower than North-West and Limpopo (mean = 2.82), and North-West is higher than Mpumalanga (mean = 2.71) compared to the positive impacts of indirect employment (i.e., increased employment from indirect mining-related companies and new business opportunities in the community). The local people of North-West are more aware than Gauteng (Effect size = 0.61) about indirect employment from the mines.

Respondents from the North-West (mean = 3.03) indicated that the positive impacts or benefits of indirect employment in the community are higher, compared to those from Gauteng (mean = 2.46) (see Table 5.28).

The concerns are that the community does not experience the positive impacts of employment that result in new business opportunities in the area and increased employment from companies contracted to the mines.

The effect size for the positive impacts of indirect employment (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) is 0.38 (see Table 5.28), showing that people from Limpopo (mean = 2.82) indicated that the positive impacts or benefits of indirect employment in the community are higher, compared to those from Gauteng (mean = 2.46).

The effect size for the positive impacts of indirect employment (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) is 0.39 (see Table 5.28), showing that people from the North-West (mean = 3.03) indicated that the positive impacts or benefits of indirect employment in the community are higher, compared to those from Mpumalanga (mean = 2.71). Gauteng province is lower than North-West, and North-West is higher than Limpopo compared to the positive impacts of direct employment from the mines in the community.

Table 5.28: Different aspects of the framework compared to the geographical location according to ANOVA.

		N	Mean	Std. Deviation	p-value	Effect sizes Gauteng with	NW with	Limpopo with
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	Gauteng	177	2.46	0.94	0.000			
	North-West	202	3.03	0.84		0.61		
	Limpopo	151	2.82	0.94		0.38	0.23	
	Mpumalanga	160	2.71	0.83		0.26	0.39	0.12
	Total	690	2.77	0.91				
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	Gauteng	177	3.43	0.96	0.000			
	North-West	202	3.87	0.72		0.46		
	Limpopo	151	3.47	0.83		0.04	0.48	
	Mpumalanga	160	3.71	0.90		0.30	0.17	0.27
	Total	690	3.63	0.87				
Employment_negative_environmental (b10, c10) {Negative impacts on water and environmental conditions)	Gauteng	177	2.57	1.16	0.000			
	North-West	202	2.15	1.02		0.36		
	Limpopo	151	2.64	1.20		0.06	0.41	
	Mpumalanga	160	2.07	0.91		0.43	0.08	0.48
	Total	690	2.35	1.10				
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Gauteng	177	3.99	0.68	0.003			
	North-West	202	3.74	0.64		0.36		
	Limpopo	151	3.72	0.85		0.32	0.03	
	Mpumalanga	160	3.84	0.85		0.17	0.12	0.14

		N	Mean	Std. Deviation	p-value	Effect sizes Gauteng with	NW with	Limpopo with
	Total	690	3.82	0.76				
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Gauteng	177	2.72	1.09	0.109			
	North-West	202	2.48	0.89		0.22		
	Limpopo	151	2.64	0.93		0.08	0.17	
	Mpumalanga	160	2.65	1.00		0.07	0.16	0.01
	Total	690	2.62	0.98				
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Gauteng	177	2.72	1.11	0.000			
	North-West	202	2.40	0.83		0.29		
	Limpopo	151	2.58	0.88		0.12	0.21	
	Mpumalanga	160	2.07	0.80		0.58	0.39	0.58
	Total	690	2.45	0.94				
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Gauteng	177	4.02	1.12	0.000			
	North-West	202	3.27	1.26		0.59		
	Limpopo	151	3.86	1.19		0.13	0.47	
	Mpumalanga	160	3.66	1.12		0.32	0.30	0.17
	Total	690	3.68	1.21				
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Gauteng	177	1.89	1.00	0.000			
	North-West	202	1.60	0.91		0.29		
	Limpopo	151	2.06	0.99		0.17	0.46	
	Mpumalanga	160	1.52	0.78		0.37	0.09	0.54
	Total	690	1.76	0.95				

		N	Mean	Std. Deviation	p-value	Effect sizes		Limpopo with
						Gauteng with	NW with	
Settlement_positive_schools (c15) {Positive impacts on schools built}	Gauteng	177	2.92	1.27	0.675			
	North-West	202	2.89	1.19		0.03		
	Limpopo	151	2.83	1.24		0.07	0.05	
	Mpumalanga	160	3.00	1.37		0.06	0.08	0.13
	Total	690	2.91	1.26				
Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)	Gauteng	177	4.08	0.77	0.039			
	North-West	202	4.05	0.72		0.04		
	Limpopo	151	3.84	1.01		0.24	0.21	
	Mpumalanga	160	4.03	0.85		0.06	0.03	0.19
	Total	690	4.01	0.83				

Respondents indicated that Gauteng province (mean = 3.43) is lower than North-West (mean = 3.87), and North-West is higher than Limpopo (mean = 3.47) compared to the positive impacts of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, training and improvement of skills) from the mines in the community. The effect sizes (0.46 and 0.48) for the positive impacts of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, training and improvement of skills) are important in practice. Respondents from the North-West indicated that the positive impacts or benefits of direct employment in the community are higher, more than those from Limpopo province and Gauteng as a result of the mines.

Respondents have indicated that the negative impact of mining on environmental conditions and water quality from Gauteng province is higher than North-West (mean = 2.15) and Mpumalanga; North-West is lower than Limpopo province and Limpopo province is higher than Mpumalanga in the community as a result of the mines. The effect size for the negative impacts of employment negatives on the environment (i.e., environmental management, minimisation, disposal, recycling and littering) and water quality (reduction, contamination and management) is important in practice. Respondents from Mpumalanga province (mean = 2.07) indicated that the negative impacts on the water quality and environmental conditions are lower in the community, more than those from Gauteng (mean = 2.57, effect size = 0.43) and Limpopo (mean = 2.64, effect size = 0.48).

The effect size for the negative impacts of employment negatives on the environment (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) is 0.36 (see Table 5.28).

Respondents from the North-West (mean = 2.15) indicated that the negative impacts on the water and environmental conditions are lower in the community, more than those from Gauteng province (mean = 2.57).

The effect size for the negative impacts of employment negatives on the environment (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) is 0.41 (see Table 5.28). Respondents from Limpopo province (mean = 2.64) indicated that the negative impacts on the water and environmental conditions are higher in the community, more than those from the North-West (mean = 2.15).

The effect size for the negative impacts of employment negatives on the environment (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) is important in practice (see Table 5.28). Respondents from Mpumalanga province (mean = 2.07) indicated that the negative impacts on the water and environmental conditions are lower in the community, more than those from Gauteng province (mean = 2.57, effect size = 0.43) and Limpopo province (mean = 2.64, effect size = 0.48).

Gauteng province is higher than North-West compared to the negative impacts of increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy on the community due to the mines.

The effect size for the negative impacts of employment negatives on social migration (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) is 0.36 (see Table 5.28). People from Gauteng (mean = 3.99) indicated that the negative impacts on social migration issues are higher in their community, compared to the North-West (mean = 3.74) because of the mines in their area.

Gauteng, the North-West, and Limpopo provinces are higher than Mpumalanga compared to the negative impacts of the environment such as pollution, damaged houses and the impact of labour strikes on work function.

The effect size for the negative impacts of environmental negatives of mining (i.e., pollution, damaged houses, and the impact of labour strikes on work function) is important in practice (see Table 5.28). Respondents from Mpumalanga province (mean = 2.07) believe that the impacts of environmental negatives of mine are lower, compared to Gauteng province (mean = 2.72, effect size = 0.58), the North-West (mean = 2.40, effect size = 0.39), and Limpopo (mean = 2.58, effect size = 0.58).

Gauteng is higher than North-West, and North-West is higher than Limpopo compared to the negative impacts of community strikes due to the mines. Most of the respondents from Gauteng and North-West believe that the mines are not doing enough for their immediate communities.

The effect size for the negative impacts of environmental negatives on community (i.e., community strikes) is 0.59 (see Table 5.28). Respondents from Gauteng province (mean = 4.02) indicated that the negative impacts of community strikes are higher in the community, more than those from North-West province (mean = 3.27).

The effect size for the negative impacts of environmental negatives on community (i.e., community strikes) is 0.47 (see Table 5.28). Respondents from Limpopo province (mean = 3.86) indicated that the negative impacts of community strikes are higher in the community, compared to the North-West province (mean = 3.27).

Gauteng and Limpopo provinces are higher than Mpumalanga; and North-West is lower than Limpopo compared to the positive impacts on relocation, compensation and housing in the community as a result of the mines in the area.

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) is 0.46 (see Table 5.28). People from Limpopo province (mean = 2.06) indicated that the positive benefits of relocation, compensation and housing are higher in the community, compared to the people from North-West province (mean = 1.60). Community members in the rural areas were compensated for relocation and damages due to blasting operations in the Limpopo province.

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) is important in practice (see Table 5.28). People from Mpumalanga province (mean = 1.52) indicated that the positive benefits of relocation, compensation and housing are lower in the community, compared to the people from Gauteng province (mean = 1.89, effect size = 0.37) and Limpopo province (mean = 2.06), effect size = 0.54).

5.4.3.2. Different aspects of the framework compared to relationship in the household

The relationship of members with other members in the household is compared to the positive impacts of direct and indirect employment, positive impacts on community environment projects, negative impacts on the environment, positive impacts on housing and settlement, and negative impacts on settlement related to informal settlement, property prices, population and infrastructure (see Table 5.29). Members in the household can be the breadwinner, spouse, child (son/daughter) and any other member such as a relative, and so on.

The spouse compared with the other members of the family has indicated lower positive impacts of increased employment from indirect mining-related companies and new business opportunities in the community.

The effect size for the positive impacts of indirect employment (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) is important in practice (see Table 5.29), showing that other members of the household (mean = 3.15) think that the positive impacts or benefits of indirect employment in the community are higher, compared to the spouse (mean = 2.61, effect size = 0.47) and the child (mean = 2.72, effect size = 0.38).

The breadwinner (i.e., member contributing main source of income) compared with the child in the household has indicated higher positive impacts of improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills in the community because of the mines.

The effect size for the positive impacts of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills) is 0.45 (see Table 5.29). The breadwinner (mean = 3.74) in the household thinks that the positive impacts or benefits of direct employment in the community are higher compared to the son/daughter in the household (mean = 3.35) as a result of the mines.

The breadwinner compared with the child and other members in the household has indicated lower negative impacts on water and environmental conditions in the community.

Table 5.29: Different aspects of the framework compared to relationship in the household according to ANOVA

		N	Mean	Std. Deviation	p-value	Effect sizes Bread winner with	 Spouse with	 Child with
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	Bread winner	478	2.79	0.85	0.098	-	-	-
	Spouse	94	2.61	1.04		0.17	-	-
	Son / Daughter	101	2.72	0.97		0.07	0.11	-
	Other	17	3.15	1.13		0.32	0.47	0.38
	Total	690	2.77	0.91				
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	Bread winner	478	3.74	0.80	0.000			
	Spouse	94	3.45	1.05		0.28		
	Son / Daughter	101	3.35	0.87		0.45	0.10	
	Other	17	3.35	1.08		0.36	0.09	0.01
	Total	690	3.63	0.87				
Employment_negative_environmental (b10, c10) {Positive impacts on water and environ-conditions)	Bread winner	478	2.15	1.00	0.000			
	Spouse	94	2.38	1.01		0.23		
	Son / Daughter	101	3.22	1.21		0.89	0.69	
	Other	17	2.59	1.08		0.41	0.19	0.52
	Total	690	2.35	1.10				
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Bread winner	478	3.81	0.73	0.000			
	Spouse	94	3.91	0.84		0.12		
	Son / Daughter	101	3.90	0.68		0.12	0.02	
	Other	17	3.00	1.04		0.78	0.88	0.86
	Total	690	3.82	0.76				

		N	Mean	Std. Deviation	p-value	Effect sizes		
						Bread winner with	Spouse with	Child with
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Bread winner	478	2.55	0.96	0.025			
	Spouse	94	2.71	1.06		0.15		
	Son / Daughter	101	2.86	0.99		0.31	0.14	
	Other	17	2.57	0.82		0.02	0.13	0.29
	Total	690	2.62	0.98				
Environmental_negative_mine (a13, d13, c13) {Positive impacts on environment: pollution, house damages, union strikes)	Bread winner	478	2.36	0.93	0.000			
	Spouse	94	2.42	0.92		0.07		
	Son / Daughter	101	2.83	0.97		0.48	0.42	
	Other	17	2.80	0.69		0.48	0.42	0.02
	Total	690	2.45	0.94				
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Bread winner	478	3.65	1.22	0.092			
	Spouse	94	3.86	1.03		0.17		
	Son / Daughter	101	3.75	1.28		0.08	0.09	
	Other	17	3.12	1.22		0.44	0.61	0.50
	Total	690	3.68	1.21				
Settlement_positive_housing (a15, b15, d15) {Positve impacts on relocation, compensation, housing}	Bread winner	478	1.62	0.88	0.000			
	Spouse	94	1.76	0.97		0.15		
	Son / Daughter	101	2.34	1.02		0.71	0.57	
	Other	17	2.25	0.86		0.73	0.51	0.08
	Total	690	1.76	0.95				
Settlement_positive_schools	Bread winner	478	2.96	1.27	0.086			

		N	Mean	Std. Deviation	p-value	Effect sizes		
						Bread winner with	Spouse with	Child with
(c15) {Positive impacts on schools built}	Spouse	94	2.96	1.29		0.00		
	Son / Daughter	101	2.69	1.24		0.21	0.20	
	Other	17	2.41	0.94		0.43	0.42	0.23
	Total	690	2.91	1.26				
Settlement_negative (a16, b16, c16, d16) {Positive impacts on informal settlement, rental prices, population, infrastructure}	Bread winner	478	4.10	0.77	0.000			
	Spouse	94	3.96	0.84		0.17		
	Son / Daughter	101	3.80	0.93		0.32	0.17	
	Other	17	2.94	1.02		1.14	1.00	0.84
	Total	690	4.01	0.83				

The effect size for the negative impacts of employment negatives on environment (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) is important in practice (see Table 5.29). The son/daughter (mean = 3.22) in the household thinks that the negative impacts on the water and environmental conditions are higher, more than the spouse (mean = 2.38, effect size = 0.69) and breadwinner (mean = 2.15, effect size = 0.89).

The effect size for the negative impacts of employment negatives on the environment (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) is 0.41 (see Table 5.29). The other members in the household (mean = 2.59) think that the negative impacts on the water and environmental conditions are higher, compared to the breadwinner (mean = 2.15).

The spouse compared with the other member of the household has indicated higher negative impacts of increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy in the community.

The effect size for the negative impacts of employment negatives on social migration (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) is important in practice (see Table 5.29). The spouse (mean = 3.91, effect size = 0.88), breadwinner (mean = 3.81, effect size = 0.78) and child (mean = 3.90, effect size = 0.86) believe that the negative impacts on social migration issues are higher, compared to the other members in the household (mean = 3.00).

The breadwinner compared with the child in the household has indicated lower negative impacts on pollution, damaged houses, and impact of labour strikes on work function in the community.

The effect size for the negative impacts of environmental negatives of mine (i.e., pollution, damaged houses, and impact of labour strikes on work function) is important in practice (see Table 5.29). The son/daughter (mean = 2.83) in the household believes that the negative impacts of pollution, house damages and union strikes are higher, compared to the breadwinner (mean = 2.36, effect size = 0.48) and spouse (mean = 2.42, effect size = 0.42).

The effect size for the negative impacts of environmental negatives of mine (i.e., pollution, damaged houses, and impact of labour strikes on work function) is important in practice (see Table 5.29). The other members in the household (mean = 2.80) believe that the negative impacts of pollution, house damages and union strikes are higher, compared to the breadwinner (mean = 2.36, effect size = 0.48) and spouse (mean = 2.42, effect size = 0.42).

A child compared to the other members in the household has indicated higher negative impacts of community strikes as a result of mines.

The effect size for the negative impacts of environmental negatives on community (i.e., community strikes) is important in practice (see Table 5.29). The spouse (mean = 3.86, effect size = 0.61), breadwinner (mean = 3.65, effect size = 0.44) and child (mean = 3.75, effect size = 0.50) believe that the negative impacts of community strikes are higher, compared to the other members in the household (mean = 3.12).

The breadwinner has indicated lower impacts than the child and other members in the household, and the child has indicated higher impacts than the other members compared to the positive impacts of resettlement to better areas, adequate compensation for displacement, and adequate houses built in the community by the mines.

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, adequate houses built) is 0.71 (see Table 5.29). The son/daughter (mean = 2.34) in the household believes that the positive benefits of relocation, compensation and housing are higher, compared to the breadwinner (mean = 1.62) as a result of the mines.

The effect size for the positive impacts of settlement positives on schools (i.e., adequate schools built) is important in practice (see Table 5.29). The other members of the household (mean = 2.41) believe that the positive benefits of adequate schools built in the community as a result of the mines are lower, compared to the breadwinner (mean = 2.96, effect size = 0.43) and spouse (mean = 2.96, effect size = 0.42).

The breadwinner, spouse and child have indicated higher negative impacts of increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services compared to the other member in the household as a result of mines.

The effect size for the negative impacts of settlement negatives (i.e., increased informal settlement, higher rental and house prices; increased population, inadequate infrastructure and poor services) is important in practice (see Table 5.29). The other members of the household (mean = 2.94) think that the negative impacts of informal settlement, rental prices, population and service delivery are lower, compared to the breadwinner (mean = 4.10, effect size = 1.14), spouse (mean = 3.96, effect size = 1.00) and child (mean = 3.80, effect size = 0.84).

5.4.3.6. Different aspects of the framework compared to the household's main source of income

The household's main source of income is compared to the positive impacts of direct and indirect employment, positive impacts on community environment projects, negative impacts on environment, positive impacts on housing and settlement, and negative impacts on settlement related to informal settlement, property prices, population and infrastructure (see

Table 5.30). Sources of income are salary, own business, social grants and any other source.

Respondents have indicated that the salary as a main source of income is higher than social grants and other sources, and own business is higher than the salary compared to the positive benefits of indirect employment (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) as a result of mines operating in their community. The effect size for the positive impacts of indirect employment (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) is important in practice (see Table 5.30), showing that people earning their main income from other sources (mean = 2.38) indicated that the positive impacts or benefits of indirect employment are lower compared to those who receive main source of income from their own business (mean = 2.86, effect size = 0.43) and a salary (mean = 2.81, effect size = 0.40).

The salary from the mines as a main source of income is higher in the direct employment benefits from mining. Respondents have indicated that income from their own business is higher than social grants and other income, and mine employees' salary is higher than own business income compared to the positive benefits of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills) in the community.

The effect size for the positive impacts of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills) is 0.86 (see Table 5.30). The people earning their main source of income from the social grants (mean = 2.97) think that the positive impacts or benefits of direct employment are lower compared to those whose main source of income is from their salary (mean = 3.76).

Table 5.30: Different aspects of the framework compared to the household's main source of income according to ANOVA

		N	Mean	Std. Deviation	p-value	Effect sizes Salary with	Own business with	Grant with
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	Salary	569	2.81	0.87	0.009			
	Own business	22	2.86	1.13		0.05		
	Social grant	67	2.54	1.01		0.26	0.28	
	Other	32	2.38	1.09		0.40	0.43	0.16
	Total	690	2.77	0.91				
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	Salary	569	3.76	0.78	0.000			
	Own business	22	3.44	1.13		0.28		
	Social grant	67	2.97	0.92		0.86	0.41	
	Other	32	2.88	1.05		0.84	0.50	0.09
	Total	690	3.63	0.87				
Employment_negative_environmental (b10, c10) {Negative impacts on water and environmental conditions)	Salary	569	2.18	0.99	0.000			
	Own business	22	2.34	1.22		0.14		
	Social grant	67	3.49	1.11		1.17	0.94	
	Other	32	3.06	1.21		0.73	0.59	0.35
	Total	690	2.35	1.10				
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Salary	569	3.80	0.73	0.000			
	Own business	22	3.42	1.01		0.37		
	Social grant	67	4.16	0.60		0.49	0.73	
	Other	32	3.79	0.98		0.01	0.36	0.38

		N	Mean	Std. Deviation	p-value	Effect sizes Salary with	Own business with	Grant with
	Total	690	3.82	0.76				
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Salary	569	2.63	0.97	0.122			
	Own business	22	2.71	0.99		0.09		
	Social grant	67	2.68	0.99		0.05	0.04	
	Other	32	2.22	1.09		0.38	0.45	0.42
	Total	690	2.62	0.98				
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Salary	569	2.38	0.91	0.000			
	Own business	22	2.29	0.74		0.10		
	Social grant	67	2.93	1.11		0.50	0.58	
	Other	32	2.76	1.00		0.38	0.47	0.15
	Total	690	2.45	0.94				
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Salary	569	3.65	1.19	0.382			
	Own business	22	3.86	1.17		0.18		
	Social grant	67	3.90	1.29		0.19	0.02	
	Other	32	3.59	1.41		0.04	0.19	0.21
	Total	690	3.68	1.21				
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Salary	569	1.67	0.89	0.000			
	Own business	22	1.98	0.92		0.34		
	Social grant	67	2.20	1.12		0.47	0.20	
	Other	32	2.19	1.16		0.45	0.18	0.01

		N	Mean	Std. Deviation	p-value	Effect sizes Salary with	Own business with	Grant with
	Total	690	1.76	0.95				
Settlement_positive_schools (c15) {Positive impacts on schools built}	Salary	569	2.97	1.23	0.036			
	Own business	22	2.50	1.54		0.31		
	Social grant	67	2.72	1.35		0.19	0.14	
	Other	32	2.50	1.37		0.34	0.00	0.16
	Total	690	2.91	1.26				
Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)	Salary	569	4.07	0.77	0.000			
	Own business	22	3.56	1.23		0.42		
	Social grant	67	3.79	0.98		0.28	0.19	
	Other	32	3.65	1.02		0.41	0.07	0.14
	Total	690	4.01	0.83				

The effect size for the positive impacts of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills) is important in practice (see Table 5.30). Those earning their main income from other sources (mean = 2.88) indicated that the positive impacts or benefits of indirect employment are lower, compared to those who receive their main source of income from their own business (mean = 3.44, effect size = 0.50) and salary (mean = 3.76, effect size = 0.84).

The effect size for the negative impacts of employment negatives on the environment (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) is 0.94 (see Table 5.30). The people with their main source of income from the social grants (mean = 3.49) indicated that the negative impacts on the water and environmental conditions are higher compared to those who receive their main source of income from their own business (mean = 2.34).

Respondents earning social grants as the main source of income and other income indicated higher negative impacts than those whose main income is from their salary and own business compared to the negative impacts of water (i.e., quality, reduction, contamination and management) and environmental conditions (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) in the community as a result of the mines. The effect size is important in practice. People earning their main income from social grants (mean = 3.49) and other sources (mean = 3.06) think that the negative impacts on the water quality and environmental conditions are higher, compared to those who receive their main source of income from their own business (mean = 2.34, effect size = 0.73) and salary (mean = 2.18, effect size = 0.59).

The effect size for the negative impacts of employment negatives on social migration (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) is 0.37 (see Table 5.30). The people earning their main source of income from their own business (mean = 3.42) think that the negative impacts on social migration issues are lower, compared to those who receive their main source of income from the salary (mean = 3.80).

Respondents earning social grants as the main source of income indicated higher negative impacts than those earning their main income from their salary, other income and their own business income compared with the negative impacts of social issues (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) in the community as a result of the mines. The effect size is important in practice. The people earning their main source of income from the social grants (mean = 4.16) think that the negative impacts on social migration issues are higher, compared to those who receive their main source of income from own business (mean = 3.42, effect size = 0.73) and those earning income from their salary (mean = 3.80, effect size = 0.49).

The effect size for the negative impacts of employment negatives on social migration (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) is 0.38 (see Table 5.30). The people earning their main source of income from other sources (mean = 3.79) think that the negative impacts on social migration issues are lower, compared to those who receive their main source of income from social grants (mean = 4.16).

The effect size for the positive impacts of environmental positives (i.e., improved health services, educational facilities, bursaries and scholarships) is important in practice (see Table 5.30). The people earning their main source of income from other sources (mean = 2.22) think that the positive impacts and benefits of improved health, educational facilities, bursaries and scholarships are lower, compared to those who receive their main source of income from their own business (mean = 2.71, effect size =

0.45), those earning income from their salary (mean = 2.63, effect size = 0.38) and those receiving social grants (mean = 2.68, effect size = 0.42).

Responses from people earning their main source of income from social grants have indicated higher negative impacts of pollution, damaged houses, and impact of labour strikes on work function than salary earners and own-business income earners. The effect size is important in practice. The people earning their main source of income from the social grants (mean = 2.93) think that the negative impacts of pollution, house damages and union strikes are higher, compared to those who receive their main source of income from own business (mean = 2.29, effect size = 0.58) and those earning income from their salary (mean = 2.38, effect size = 0.50).

The effect size for the negative impacts of environmental negatives of mines (i.e., pollution, damaged houses, and impact of labour strikes on work function) is important in practice (see Table 5.30). The people earning their main source of income from other sources (mean = 2.76) think that the negative impacts of pollution, house damages and union strikes are higher, compared to those who receive their main source of income from their own business (mean = 2.29).

People earning their main source of income from their salary have indicated lower positive impacts than social grants and their own business income earners compared to positives of housing and settlement. The effect size is 0.47. The people earning their main source of income from the social grants (mean = 2.20) indicated that the positive benefits of housing and settlement (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) are higher compared with those earning income from their salary (mean = 1.67).

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) is 0.45 (see Table 5.30). The people earning their main source of income from other sources (mean =

2.19) indicated that the positive benefits of relocation, compensation and housing are higher, compared with those earning income from the salary (mean = 1.67).

People with their main source of income from their salary have indicated higher negative impacts of housing and settlement than social grants and their own business income earners compared to negatives of housing and settlement. The effect size for the negative impacts of settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) is 0.42 (see Table 5.30). The people earning their main source of income from their own business (mean = 3.56) think that the negative impacts of informal settlement, rental prices, population and service delivery are lower, compared to those earning income from their salary (mean = 4.07).

The effect size for the negative impacts of settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) is 0.41 (see Table 5.30). The people earning their main source of income from other sources (mean = 3.65) think that the negative impacts of informal settlement, rental prices, population and service delivery are lower, compared to those earning income from their salary (mean = 4.07).

5.4.3.6. Different aspects of the framework compared to place of work

The place of work or status of employment of the respondents is compared to the positive impacts of direct and indirect employment, positive impacts on community environment projects, negative impacts on environment, positive impacts on housing and settlement, and negative impacts on settlement related to informal settlement, property prices, population and infrastructure (see Table 5.31). The status of employment of respondents is divided into employed by mining operation, another sector, or unemployed.

Respondents employed by the mines have indicated higher positive impacts than the unemployed compared with the positive impacts of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, training and improvement of skills). The respondents who are unemployed (mean = 3.00) think that the positive impacts or benefits of direct employment are lower compared to those working in the mining (mean = 3.70, effect size = 0.77) and those working in other sectors (mean = 3.78, effect size = 0.85).

Respondents employed by the mines have indicated lower negative impacts than the unemployed and others compared to the negative impacts of environmental conditions (i.e., environmental management, minimisation, disposal, recycling and littering) and water quality (i.e., quality, reduction, contamination and management). The respondents who are unemployed (mean = 3.41) indicated that the negative impacts on the water and environmental conditions are higher, compared to those working in the mining (mean = 2.25, effect size = 1.04) and those working in other sectors (mean = 2.08, effect size = 1.20).

Respondents employed by the mines have indicated lower negative impacts than the unemployed and others compared to the negative impacts of social migration issues (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy). The effect size is 0.40 (see Table 5.31). The respondents who are unemployed (mean = 4.06) think that the negative impacts of social migration issues are lower compared to those working in mining (mean = 3.77) and other sectors.

Table 5.31: Different aspects of the framework compared to place of work according to ANOVA – Descriptives

		N	Mean	Std. Deviation	p-value	Effect sizes Mining with	Effect sizes Other with
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	Mining	380	2.78	0.85	0.054		
	Other	219	2.82	0.94		0.04	
	Unemployed	91	2.55	1.03		0.22	0.26
	Total	690	2.77	0.91			
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	Mining	380	3.70	0.81	0.000		
	Other	219	3.78	0.85		0.09	
	Unemployed	91	3.00	0.91		0.77	0.85
	Total	690	3.63	0.87			
Employment_negative_environmental (b10, c10) {Negative impacts on water and environ-conditions)	Mining	380	2.25	1.00	0.000		
	Other	219	2.08	1.00		0.17	
	Unemployed	91	3.41	1.11		1.04	1.20
	Total	690	2.35	1.10			
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Mining	380	3.77	0.73	0.004		
	Other	219	3.81	0.81		0.05	
	Unemployed	91	4.06	0.69		0.40	0.31
	Total	690	3.82	0.76			
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Mining	380	2.64	0.93	0.631		
	Other	219	2.56	1.04		0.07	
	Unemployed	91	2.65	1.03		0.01	0.08
	Total	690	2.62	0.98			

		N	Mean	Std. Deviation	p-value	Effect sizes Mining with	 Other with
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Mining	380	2.46	0.94	0.000		
	Other	219	2.27	0.84		0.19	
	Unemployed	91	2.81	1.10		0.32	0.49
	Total	690	2.45	0.94			
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Mining	380	3.62	1.17	0.347		
	Other	219	3.76	1.21		0.12	
	Unemployed	91	3.74	1.38		0.08	0.02
	Total	690	3.68	1.21			
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Mining	380	1.69	0.90	0.000		
	Other	219	1.67	0.90		0.03	
	Unemployed	91	2.23	1.11		0.49	0.51
	Total	690	1.76	0.95			
Settlement_positive_schools (c15) {Positive impacts on schools built}	Mining	380	2.94	1.18	0.571		
	Other	219	2.89	1.35		0.04	
	Unemployed	91	2.79	1.37		0.11	0.08
	Total	690	2.91	1.26			
Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)	Mining	380	4.07	0.77	0.006		
	Other	219	4.00	0.85		0.08	
	Unemployed	91	3.76	0.98		0.32	0.25
	Total	690	4.01	0.83			

The people that are unemployed have indicated higher negative impacts than those employed by mining and in other sectors compared to the negative impacts of pollution, damaged houses, and impact of labour strikes on work function. The effect size is 0.49. The respondents who are unemployed (mean = 2.81) think that the negative impacts of pollution, house damages and union strikes are higher, compared to those working in other sectors (mean = 2.27).

Respondents employed by the mines have indicated lower positive impacts than the unemployed, compared to the positive impacts of housing and settlement (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built). The respondents who are unemployed (mean = 2.23) indicated that the positive benefits of housing and settlement are higher, compared to those working in mining (mean = 1.69, effect size = 0.49) and those working in other sectors (mean = 1.67, effect size = 0.51).

5.4.3.6. Different aspects of the framework compared to current work (employment) status

The current work (employment contract) status of the respondents is compared to the positive impacts of direct and indirect employment, positive impacts on community environment projects, negative impacts on environment, positive impacts on housing and settlement, and negative impacts on settlement related to informal settlement, property prices, population and infrastructure. The employment contract of respondents is categorised into permanent, contract, part-time, or unemployed.

Respondents who are permanently employed have indicated higher positive impacts from the mines than part-time, contract and unemployed people compared to the positive benefits of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills). The respondents who are employed on a part-time basis (mean = 2.69) and the unemployed (mean = 2.96) believe that the positive impacts or benefits of direct employment are lower, compared to those with permanent employment (mean = 3.81, effect size = 0.86) and those employed on a contract basis (mean = 3.56, effect size = 0.67). It is believed that permanent employment offers job security compared to part-time employment.

The effect size for the positive impacts of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, and training and improvement of skills) is important in practice (see Table 5.32). The respondents who are unemployed (mean = 2.96) think that the positive impacts or benefits of direct employment are lower, compared to those with permanent employment (mean = 3.81, effect size = 0.94) and those employed on a contract basis (mean = 3.56, effect size = 0.65).

People who are employed on a contract basis, permanently and on a part-time basis indicated the lower negative impacts than the unemployed when compared to the negative impacts of water and environmental conditions (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management). The respondents who are unemployed (mean = 3.44) indicated that the negative impacts on the water and environmental conditions are higher, compared to those with permanent employment (mean = 2.12, effect size = 1.17), those employed on a contract basis (mean = 2.40, effect size = 0.92) and those employed on a part-time basis (mean = 2.44, effect size = 0.68). The unemployed believe that employed members have access to clean water at their places on employment compared to them at home.

Table 5.32: Different aspects of the framework compared to current work (employment) status according to ANOVA

		N	Mean	Std. Deviation	p-value	Effect sizes Permanent with	Effect sizes Contract with	Part-time with
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	Permanent	447	2.87	0.88	0.001			
	Contract	146	2.63	0.87		0.26		
	Part-time	8	2.50	1.04		0.35	0.13	
	Unemployed	89	2.50	1.03		0.35	0.13	0.00
	Total	690	2.77	0.91				
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	Permanent	447	3.81	0.75	0.000			
	Contract	146	3.56	0.92		0.27		
	Part-time	8	2.69	1.30		0.86	0.67	
	Unemployed	89	2.96	0.91		0.94	0.65	0.21
	Total	690	3.63	0.87				
Employment_negative_environmental (b10, c10) {Negative impacts on water and environmental conditions)	Permanent	447	2.12	0.93	0.000			
	Contract	146	2.40	1.13		0.25		
	Part-time	8	2.44	1.47		0.22	0.03	
	Unemployed	89	3.44	1.13		1.17	0.92	0.68
	Total	690	2.35	1.10				
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Permanent	447	3.83	0.68	0.000			
	Contract	146	3.66	0.90		0.19		
	Part-time	8	3.20	1.25		0.51	0.37	
	Unemployed	89	4.07	0.72		0.32	0.45	0.69

		N	Mean	Std. Deviation	p-value	Effect sizes Permanent with	Contract with	Part-time with
	Total	690	3.82	0.76				
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Permanent	447	2.59	0.95	0.610			
	Contract	146	2.71	1.00		0.12		
	Part-time	8	2.54	1.75		0.03	0.10	
	Unemployed	89	2.59	1.02		0.00	0.12	0.03
	Total	690	2.62	0.98				
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Permanent	447	2.35	0.90	0.000			
	Contract	146	2.47	0.88		0.13		
	Part-time	8	2.46	1.32		0.08	0.01	
	Unemployed	89	2.86	1.09		0.46	0.35	0.30
	Total	690	2.45	0.94				
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Permanent	447	3.67	1.17	0.854			
	Contract	146	3.66	1.22		0.00		
	Part-time	8	3.63	1.30		0.03	0.03	
	Unemployed	89	3.79	1.38		0.09	0.09	0.12
	Total	690	3.68	1.21				
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Permanent	447	1.63	0.86	0.000			
	Contract	146	1.85	0.97		0.23		
	Part-time	8	1.71	1.16		0.07	0.12	
	Unemployed	89	2.25	1.14		0.55	0.35	0.47
	Total	690	1.76	0.95				

		N	Mean	Std. Deviation	p-value	Effect sizes Permanent with	Contract with	Part-time with
Settlement_positive_schools (c15) {Positive impacts on schools built}	Permanent	447	3.01	1.25	0.015			
	Contract	146	2.77	1.21		0.19		
	Part-time	8	2.00	1.20		0.81	0.63	
	Unemployed	89	2.73	1.38		0.20	0.03	0.53
	Total	690	2.91	1.26				
Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)	Permanent	447	4.10	0.73	0.000			
	Contract	146	3.89	0.92		0.23		
	Part-time	8	3.63	1.39		0.34	0.19	
	Unemployed	89	3.73	1.02		0.36	0.16	0.08
	Total	690	4.01	0.83				

Respondents that are unemployed have indicated higher negative impacts than those employed on a permanent, contract and part-time basis compared to social migration issues (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy). The respondents who are employed on a part-time basis (mean = 3.20) believe that the positive impacts or benefits of employment negatives on social migration are lower, compared to those with permanent employment (mean = 3.83, effect size = 0.51) and those employed on a contract basis (mean = 2.44, effect size = 0.37). Migrants are mostly employed on part-time basis in the community.

The effect size for the negative impacts of employment negatives on social migration (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) is important in practice (see Table 5.32). The respondents who are unemployed (mean = 4.07) indicated that the positive impacts or benefits of employment negatives on social migration are higher, compared to those employed on a part-time basis (mean = 3.20, effect size = 0.45) and those employed on a contract basis (mean = 3.66, effect size = 0.69). The unemployed believe that migrants are taking their jobs.

Permanently employed respondents have indicated lower impacts than unemployed respondents compared to the negative impacts of environmental issues (i.e., pollution, damaged houses, and impact of labour strikes on work function). The effect size is 0.46. The respondents who are unemployed (mean = 2.86) indicated that the negative impacts of pollution, house damages and union strikes are higher, compared to those with permanent employment (mean = 2.47). The unemployed in the community are normally blocking access roads during strikes and affecting the employed members.

Respondents employed on a permanent and part-time basis have indicated lower impacts than the unemployed to the positive impacts of housing and settlement (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built). The respondents who are unemployed (mean = 2.25) indicated that the positive benefits of relocation, compensation and housing are lower, compared to those with permanent employment (mean = 1.63, effect size = 0.55) and those employed on a part-time basis (mean = 1.71, effect size = 0.47).

People that are permanently employed have indicated higher impacts than contract employees, part-time employees and the unemployed compared to the positive impacts on adequate schools built as a result of the mines in the community. The respondents who are employed on a part-time basis (mean = 2.00) believe that the positive benefits of adequate schools built are lower, compared to those with permanent employment (mean = 3.01, effect size = 0.81), those on a contract basis (mean = 2.77, effect size = 0.63) and those who are unemployed (mean = 2.73, effect size = 0.53). The permanently employed members are concerned about overcrowding in schools and tend to enrol their children in nearby towns and cities.

Respondents that are permanently employed have indicated higher negative impacts than those who are unemployed, on part-time and contract employment compared to the negative impacts on housing and settlement (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services). The effect size for the negative impacts of settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) is 0.36. The respondents who are unemployed (mean = 3.73) indicated that the negative impacts of informal settlement, rental prices, population and service delivery are lower, compared to those with permanent employment (mean = 4.10). The unemployed, part-time and on-contract basis respondents are mostly residing in the informal settlement.

5.4.3.6. Different aspects of the framework compared to settlement (place of stay)

The settlement (place of stay) of the respondents is compared to the positive impacts of direct and indirect employment, positive impacts on community environment projects, negative impacts on environment, positive impacts on housing and settlement, and negative impacts on settlement related to informal settlement, property prices, population and infrastructure (see Table 5.33). The respondents' place of residence is the town, township, rural and informal settlement.

People that are staying in town have indicated higher positive benefits than those staying in the township, rural and informal settlement compared to the positive impacts of indirect employment (i.e., increased employment from indirect mining-related companies and new business opportunities in the community). The respondents who are staying in the township (mean = 2.71) indicated that the positive impacts or benefits of indirect employment are lower compared to those staying in town (mean = 3.11, effect size = 0.45) (see Table 5.33). Those staying in the rural area (mean = 2.66, effect size = 0.46) and informal settlement (mean = 2.71, effect size = 0.44) indicated that the positive impacts or benefits of indirect employment are lower, compared to those staying in town (mean = 3.11, effect size = 0.44). Respondents from township, rural and informal settlement believe that business opportunities are mostly offered to people in town because they have more resources than them.

Respondents staying in town believe that there are higher positive benefits than those staying in the rural area compared to the positive benefits of direct employment (i.e., improved quality of life, increased employment from the mines, more tradesmen, training and improvement of skills). The effect size is 0.61. The respondents who are staying in the rural area (mean = 3.37) think that the positive impacts or benefits of direct employment are lower, compared to those staying in town (mean = 3.89). Those staying in an informal settlement (mean = 3.60) indicated that the positive impacts or benefits of direct employment are lower, compared to those staying in town (mean = 3.89). There is a believe that mines favour people from towns because of less disruptions to work function.

The effect size for the positive impacts of environmental positives (i.e., improved health services, educational facilities, bursaries and scholarships) is 0.61 (see Table 5.33). The respondents who are staying in the township (mean = 2.27) think that the positive impacts and benefits of improved health, educational facilities, bursaries and scholarships are lower, compared to those staying in town (mean = 3.30).

The effect size for the positive impacts of environmental positives (i.e., improved health services, educational facilities, bursaries and scholarships) is important in practice (see Table 5.33). The respondents who are staying in the rural area (mean = 2.30) think that the positive impacts and benefits of improved health, educational facilities, bursaries and scholarships are lower, compared to those staying in town (mean = 3.30, effect size = 1.03) and the township (mean = 2.27, effect size = 0.48). Health services in the rural areas are far from the residents and do not have all the required facilities.

Table 5.33: Different aspects of the framework compared to settlement (place of stay) according to ANOVA.

		N	Mean	Std. Deviation	p-value	Effect sizes Town with	Township with	Rural with
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	Town	117	3.11	0.89	0.000			
	Township	268	2.71	0.85	.	0.45		
	Rural	159	2.66	0.97		0.46	0.05	
	Informal	146	2.71	0.90		0.44	0.00	0.05
	Total	690	2.77	0.91				
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	Town	117	3.89	0.81	0.000			
	Township	268	3.70	0.94		0.20		
	Rural	159	3.37	0.86		0.61	0.35	
	Informal	146	3.60	0.72		0.36	0.11	0.27
	Total	690	3.63	0.87				
Employment_negative_environmental (b10, c10) {Negative impacts on water and environmental conditions	Town	117	2.38	1.05	0.521			
	Township	268	2.33	1.13		0.05		
	Rural	159	2.44	1.15		0.05	0.10	
	Informal	146	2.26	1.03		0.11	0.06	0.16
	Total	690	2.35	1.10				
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	Town	117	3.77	0.70	0.057			
	Township	268	3.87	0.69		0.14		
	Rural	159	3.69	0.91		0.09	0.20	
	Informal	146	3.89	0.72		0.16	0.03	0.22
	Total	690	3.82	0.76				

		N	Mean	Std. Deviation	p-value	Effect sizes Town with	Township with	Rural with
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	Town	117	3.30	0.82	0.000			
	Township	268	2.77	0.88		0.61		
	Rural	159	2.30	0.97		1.03	0.48	
	Informal	146	2.11	0.89		1.34	0.74	0.19
	Total	690	2.62	0.98				
Environmental_negative_mine (a13, d13, c13) {Negative impacts on environment: pollution, house damages, union strikes)	Town	117	2.64	1.11	0.061			
	Township	268	2.45	0.94		0.17		
	Rural	159	2.38	0.95		0.24	0.08	
	Informal	146	2.35	0.76		0.26	0.11	0.02
	Total	690	2.45	0.94				
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	Town	117	3.94	0.94	0.000			
	Township	268	3.86	1.06		0.08		
	Rural	159	3.52	1.30		0.33	0.26	
	Informal	146	3.33	1.43		0.43	0.37	0.13
	Total	690	3.68	1.21				
Settlement_positive_housing (a15, b15, d15) {Positive impacts on relocation, compensation, housing}	Town	117	2.14	0.89	0.000			
	Township	268	1.72	0.89		0.47		
	Rural	159	1.80	1.00		0.34	0.09	
	Informal	146	1.47	0.94		0.71	0.26	0,33
	Total	690	1.76	0.95				
Settlement_positive_schools	Town	117	3.51	1.26	0.000			

		N	Mean	Std. Deviation	p-value	Effect sizes Town with	Township with	Rural with
(c15) {Positive impacts on schools built}	Township	268	3.09	1.19		0.34		
	Rural	159	2.43	1.22		0.86	0.54	
	Informal	146	2.62	1.17		0.71	0.40	0.15
	Total	690	2.91	1.26				
Settlement_negative (a16, b16, c16, d16) {Negative impacts on informal settlement, rental prices, population, infrastructure)	Town	117	3.84	0.70	0.000			
	Township	268	4.02	0.71		0.26		
	Rural	159	3.80	1.10		0.04	0.20	
	Informal	146	4.33	0.70		0.70	0.44	0.48
	Total	690	4.01	0.83				

People that are staying in the township, rural and informal settlement believe that there are lower positive impacts of community projects from the mines than those staying in town compared to the improved health services, educational facilities, bursaries and scholarships. The respondents who are staying in the rural areas (mean = 2.30) and informal settlement (mean = 2.11) indicated that the positive impacts and benefits of improved health, educational facilities, bursaries and scholarships are lower, compared to those staying in town (mean = 3.30, effect size = 1.34) and the township (mean = 2.27, effect size = 0.74).

People that are staying in town indicated higher impacts of community strikes as a result of the mines in their community more than those in the informal settlement. The respondents who are staying in the informal settlement (mean = 3.33) believe that the negative impacts of community strikes are lower, compared to those staying in town (mean = 3.94, effect size = 0.43) and the township (mean = 3.86, effect size = 0.37). Service delivery protests in the informal settlements tend to affect people working in towns and cities.

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, adequate houses built) is 0.47 (see Table 5.33). The respondents who are staying in the township (mean = 1.72) indicated that the positive benefits of relocation, compensation and housing are lower, compared to those staying in town (mean = 2.14). Most respondents in the township were not relocated.

The effect size for the positive impacts of settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, adequate houses built) is important in practice (see Table 5.33). The respondents who are staying in the informal settlement (mean = 1.47) indicated that the positive benefits of relocation, compensation and housing are lower, compared to those staying in town (mean = 2.14, effect size = 0.71) and the township (mean = 1.72, effect size = 0.47).

Respondents in the informal settlement moved closer to stay in the vicinity of the mining area and mining companies do not assist with housing in the informal areas.

The effect size for the positive impacts of settlement positives on schools (i.e., adequate schools built) is important in practice (see Table 5.33). The respondents who are staying in the rural areas (mean = 2.43) believe that the positive benefits of adequate schools built are lower, compared to those staying in town (mean = 3.51, effect size = 0.86) and the township (mean = 3.09, effect size = 0.54). It is believed that schools in the rural areas lack educational resources.

The effect size for the positive impacts of settlement positives on schools (i.e., adequate schools built) is practically important (see Table 5.33). The respondents who are staying in the informal settlement (mean = 2.62) believe that the positive benefits of adequate schools built are lower, compared to those staying in town (mean = 3.51, effect size = 0.71) and the township (mean = 3.09, effect size = 0.40).

The respondents who are staying in the informal settlement (mean = 4.33) indicated that the negative impacts of informal settlement, rental prices, population and service delivery are higher, compared to those staying in town (mean = 3.84, effect size = 0.70), the township (mean = 4.02, effect size = 0.44) and rural areas (mean = 3.80, effect size = 0.48). Respondents in the township, rural areas and informal settlement believe that they are overpopulated and there is poor service delivery compared to towns and cities.

5.5. Correlation of the relationship between factor scores for the positive and negative impacts in the analytical framework

This section discusses the relationship between factor scores of the indirect employment, direct employment, employment negatives of the environment, employment negatives for social migration, environmental positives, environmental negatives of the mine, environmental negatives for the community, settlement positives of housing, settlement positives of schools, and settlement negatives in the analytical framework (see Table 5.34).

Table 5.34: Correlation of the relationship between factor scores for the positive and negative impacts in the analytical framework according to ANOVA

	Employment_bussiness	Employment_general_pos	Employment_negative_environmental	Employment_negative_soc_migration	Environmental_positive	Environmental_negative_mine	Environmental_negative_community	Settlement_posititive_housing	Settlement_posititive_schools	Settlement_negaititive
Employment_business (c9, f9) {Indirect employment: Positive impacts employment}	1.000	.422**	0.071	-.085*	.333**	.084*	-0.043	.229**	.288**	-.095*
Employment_general_pos (a9, b9, d9, e9) {Direct employment: Positive impacts employment}	.422**	1.000	-.333**	0.038	.220**	-.232**	0.070	-.142**	.342**	.124**
Employment_negative_environmental (b10, c10) {Negative impacts on water and environ-conditions}	0.071	-.333**	1.000	.141**	.193**	.459**	.112**	.442**	-0.038	-0.044
Employment_negative_soc_migration (a10, d10, e10, f10, g10) {Negative impacts on social issues}	-.085*	0.038	.141**	1.000	0.008	0.047	.303**	-.107**	0.074	.301**
Environmental_positive (a12, b12, c12) {Positive impacts on community projects: health, education and bursaries}	.333**	.220**	.193**	0.008	1.000	.191**	.163**	.528**	.502**	-.234**
Environmental_negative_mine (a13, d13, c13) {Positive impacts on environment: pollution, house damages, union strikes)	.084*	-.232**	.459**	0.047	.191**	1.000	.273**	.407**	-0.065	-0.013

	Employment_bussiness	Employment_general_pos	Employment_negative_environmental	Employment_negative_soc_migration	Environmental_positive	Environmental_negative_mine	Environmental_negative_community	Settlement_posititive_housing	Settlement_posititive_schools	Settlement_negaititive
Environmental_negative_community (b13) {Negative impacts on environment: community strikes}	-0.043	0.070	.112**	.303**	.163**	.273**	1.000	0.045	.170**	.193**
Settlement_positive_housing (a15,b15,d15) {Positive impacts on relocation, compensation, housing}	.229**	-.142**	.442**	-.107**	.528**	.407**	0.045	1.000	.253**	-.345**
Settlement_positive_schools (c15) {Positive impacts on schools built}	.288**	.342**	-0.038	0.074	.502**	-0.065	.170**	.253**	1.000	-0.034
Settlement_negative (a16,b16,c16,d16) {Negative impacts on informal settlement,rental prices, population, infrastructure)	-.095*	.124**	-0.044	.301**	-.234**	-0.013	.193**	-.345**	-0.034	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

There is a positive correlation between the indirect employment aspects (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) and direct employment (r = 0.422), environmental positives (r = 0.333), environmental negatives of the mine (r = 0.084), settlement positives of housing (r = 0.229) and settlement positives of schools (r = 0.288) (see Table 5.34). The respondents who experienced higher indirect employment aspects indicated higher positive impacts or benefits of direct employment, environmental positives, environmental negatives of the mine, settlement positives of housing and settlement positives of schools in the community.

There is a negative correlation between the indirect employment aspects (i.e., increased employment from indirect mining-related companies and new business opportunities in the community) and employment negatives for social migration (r = -0.85) and settlement negatives (r = -0.095) (see Table 5.34). The respondents who experienced higher indirect employment aspects indicated lower positive impacts or benefits of employment negatives for social migration and settlement negatives. It is believed that people from outside the community are mostly benefitting from the indirect employment from the mines.

There is a positive correlation between the direct employment aspects (i.e., improved quality of life, increased employment from the mines, more tradesmen, training and improvement of skills) and direct employment (r = 0.422), environmental positives (r = 0.220), settlement positives of schools (r = 0.342) and settlement negatives (r = 0.124) (see Table 5.34). The respondents who experienced higher direct employment aspects indicated higher positive impacts and benefits of direct employment and settlement negatives. People who are directly employed by the mines are concerned about social migration in their community.

There is a negative correlation between the direct employment aspects (i.e., improved quality of life, increased employment from the mines, more tradesmen, training and improvement of skills) and employment negatives of the environment (r = -0.333) and environmental negatives of the mine (r = -0.232) and settlement positives of housing (r = -0.142) (see Table 5.34). The respondents who experienced higher direct employment aspects indicated lower positive impacts and benefits of employment negatives of the environment and environmental negatives of the mine and settlement positives of housing. People who are directly employed by the mines are not concerned about job security but concerned about people from outside their community.

There is a positive correlation between environmental conditions and water aspects (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) and environmental positives (r = 0.193), environmental negatives of mines (r = 0.459), environmental negatives for the community (r = 0.112), and settlement positives of housing (r = 0.442) (see Table 5.34). The respondents who experienced higher environmental conditions and water aspects indicated higher negative impacts of environmental positives, environmental negatives of mines, environmental negatives for the community, and settlement positives of housing.

There is a negative correlation between environmental conditions and water aspects (i.e., environmental management, minimisation, disposal, recycling and littering; and water quality, reduction, contamination and management) and direct employment (r = -0.333) (see Table 5.34). The respondents who experienced higher environmental conditions and water aspects indicated lower negative impacts of direct employment.

There is a positive correlation between employment negative social migration issues (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) and employment negatives of the environment (r = 0.141), environmental negatives for the community (r = 0.303), and settlement negatives (r = 0.301) (see Table 5.34). The respondents who experienced higher employment negatives of social migration issues indicated higher negative impacts of employment negatives of the environment, environmental negatives for the community, and settlement negatives. Respondents believe that instability and disorder in the community is related to increased migration of labour.

There is a negative correlation between employment negatives of social migration issues (i.e., increased migration of labour, land availability, high crime levels, abuse of drugs and alcohol, and teenage pregnancy) and indirect employment (r = -0.085) and settlement positives for housing (r = -0.107) (see Table 5.34). The respondents who experienced higher employment negatives of social migration issues indicated lower negative impacts of indirect employment and settlement positives for housing. It is not easy for migrants to qualify for housing benefits in the community even if they are indirectly employed by the mines.

There is a positive correlation between environmental positives (i.e., improved health services, educational facilities, bursaries and scholarships) and indirect employment (r = 0.333), direct employment (r = 0.220), employment negatives of environmental (r = 0.193), environmental negatives of the mine (r = 0.191), environmental negatives of the community (r = 0.163), settlement positives of housing (r = 0.528) and settlement positives for schools (r = 0.502) (see Table 5.34). The respondents who experienced higher environmental positives aspects indicated higher positive impacts and benefits of direct employment than indirect employment, employment negatives of environment, environmental negatives of the mine, environmental negatives of the community, settlement positives of housing, and settlement positives of schools.

There is a negative correlation between environmental positives (i.e., improved health services, educational facilities, bursaries and scholarships) and settlement negatives (r = -0.234) (see Table 5.34). The respondents who experienced higher environmental positives aspects indicated lower positive impacts and benefits of settlement negatives.

There is a positive correlation between environmental negatives of the mine (i.e., pollution, damaged houses, and impact of labour strikes on work function) and indirect employment (r = 0.084), employment negatives of the environment (r = 0.459), environmental positives (r = 0.191), environmental negatives for the community (r = 0.273), and settlement positives of housing (r = 0.407) (see Table 5.34). The respondents who experienced higher environmental negatives of the mine indicated higher negative impacts of indirect employment, employment negatives of the environment, environmental negatives for the community, and settlement positives of housing.

There is a negative correlation between environmental negatives of the mine (i.e., pollution, damaged houses, and impact of labour strikes on work function) and direct employment (r = -0.232) (see Table 5.34). The respondents who experienced higher environmental negatives of the mine indicated lower negative impacts of direct employment.

There is a positive correlation between environmental negatives in the community (i.e., community strikes or protests) and employment negatives of the environment (r = 0.112), employment negatives of social migration (r = 0.303), environmental positives (r = 0.163), environmental negatives of the mine (r = 0.273), settlement positives for schools (r = 0.170) and settlement negatives (r = 0.193) (see Table 5.34). The respondents who experienced higher environmental negatives of environmental negatives in the community indicated higher negative impacts of employment negatives of the environment, employment negatives of social migration, environmental positives, environmental negatives of the mine, settlement positives for schools and settlement negatives.

There is a positive correlation between settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, and adequate houses built) and indirect employment (r = 0.229), employment negatives of environment (r = 0.442), environmental positives (r = 0.528), environmental negatives of the mine (r = 0.407), and settlement positives of schools (r = 0.253) (see Table 5.34). The respondents who experienced higher settlement positives of housing indicated higher positive benefits and impacts of indirect employment, employment negatives of the environment, environmental positives, environmental negatives of the mine, and settlement positives of schools.

There is a negative correlation between settlement positives of housing (i.e., resettlement to better areas, adequate compensation for displacement, adequate houses built) and direct employment (r = -0.142), employment negatives of environment (r = -0.107), and settlement negatives (r = -0.345) (see Table 5.34). The respondents who experienced higher settlement positives of housing indicated lower positive benefits and impacts of indirect employment, employment negatives of social migration and settlement negatives.

There is a positive correlation between settlement positives of schools (i.e., adequate schools built) and indirect employment (r = 0.288), direct employment (r = 0.342), environmental positives (r = 0.502), environmental negatives for the community (r = 0.170) and settlement positives of housing (r = 0.253) (see Table 5.34). The respondents who experienced higher settlement positives of schools indicated higher positive benefits and impacts of indirect employment, direct employment, environmental positives, environmental negatives for the community and settlement positives of housing.

There is a positive correlation between settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) and direct employment (r = 0.124), employment negatives of social migration (r = 0.301) and environmental negatives for the community (r = 0.193) (see Table 5.34). The respondents who experienced higher settlement negatives indicated higher negative impacts of direct employment, employment negatives of social migration and environmental negatives for the community.

There is a negative correlation between settlement negatives (i.e., increased informal settlement, higher rental and house prices, increased population, inadequate infrastructure and poor services) and indirect employment (r = -0.095), environmental positives (r = -0.234), and settlement positives of housing (r = -0.345) (see Table 5.34). The respondents who experienced higher settlement negatives indicated lower negative impacts of indirect employment, environmental positives and settlement positives of housing.

5.6. Chapter summary

Main categories for the classification and development of the framework for strategic and critical minerals are economic importance, risk and impacts. In dealing with impacts of the framework, the section assessed the socio-economic impacts. The chapter focused on the direct and indirect socio-economic impacts on employment, environment, community, settlement and other related aspects. The analysis was conducted on the perceptions of local people about the socio-economic impacts of mining activities in their community.

Different statistical techniques were performed on the data collected. It was found that the data analysed was valid and reliable at Cronbach Alpha's of more than 0.7. The value of KMO was 0.800 and indicated that the sampling conducted was adequate and factor analysis was useful for the data. The analysis therefore yielded distinct and reliable constructs for the socio-economic impact factors in the framework. Further, strong correlation between indicators that were factor analysed was indicated. Correlation of the relationship between factor scores for the positive and negative impacts in the analytical framework were analysed according to ANOVA. The factors indicated either a strong positive or negative correlation. An independent sample t-test or analyses of variance were performed to test whether the means of subsamples significantly differed from each other. The effect sizes are independent of sample sizes and indicated a good measure of practical significance. The pattern matrix for the positive and negative impacts of different aspects indicated distinct constructs according to the principal component analysis.

The study identified four main impacts that influenced the perceptions of local people in the vicinity of the mining operations, that is, personal characteristics, employment and economic activities, community projects, and environment and settlement. The perceptions of respondents varied with regard to the positive and negative impacts of mining. The perceptions of local communities mostly indicated positive overall socio-economic benefits according to the assessment of impacts. In the next chapter, the main categories are used to assess strategic and critical minerals.

CHAPTER 6: ASSESSING THE FRAMEWORK FOR STRATEGIC AND CRITICAL MINERALS

6.1. Introduction

Chapter 4 and 5 developed and discussed the criticality and strategic levels of a mineral based on the socio-economic impact (i.e., analytical framework) and trends of contributions of the minerals to the economy within the overall framework.

The screening process and stages of evaluation in the classification of strategic and critical minerals in chapter 4 have been proposed. The stages of evaluation in the screening process are 1.) identification of the mineral, 2) importance of use and reliance, 3) production and growth, 4) resources and reserves, 5) marketing and demand, 6) subject matter team of experts and 7) investment.

Chapter 6 will consider 1) availability and risk of supply and 2) importance of use of a mineral in the total framework. A "Criticality Matrix" methodology using factors 1 and 2 will be used to assess the criticality and strategic status of a mineral. Impacts of the minerals on the economy are also considered.

Several parameters were identified and described in Section 2.5 and Section 4.3.1 which are pertinent to the country's situation; namely, 1) electricity (power), 2) supply, 3) demand, 4) availability, 5) utilisation, 6) geopolitical risks, 7) income, 8) employment, 9) community, 10) expertise and technology, 11) investment, 12) policy, 13) labour, 14) environment and 15) infrastructure. Finally, minerals are evaluated and ranked using three categories, that is, economic importance, risk, and impact (see Figure 6.1).

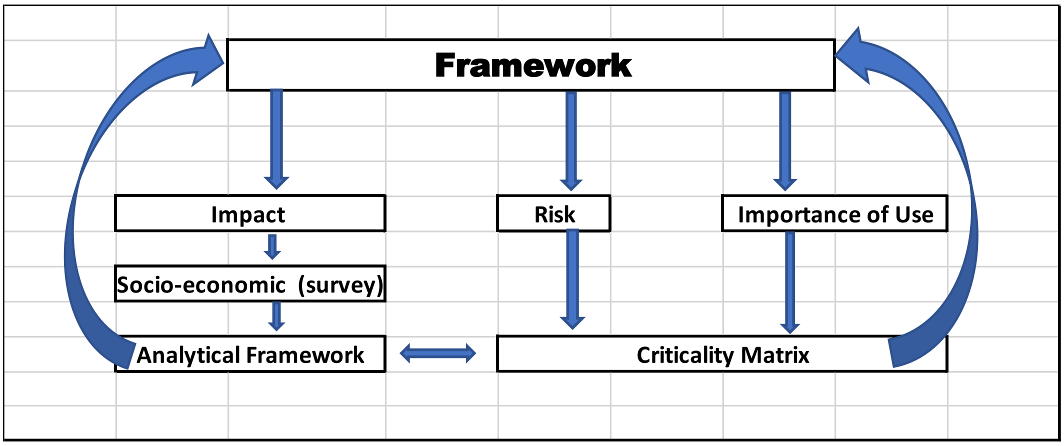


Figure 6.1: A diagram showing categories used to evaluate and rank minerals in the framework

Chapter 7 will outline the overall framework based upon the results obtained from chapter 4 to chapter 6.

6.2. Categories of the framework for strategic and critical minerals

The minerals are evaluated using three categories, that is, economic importance, risk, and impact. The elements of the parameters of the classification of strategic and critical minerals are ranked and grouped into the categories as shown in Table 6.1.

Table 6.1: Elements affecting strategic and critical minerals according to their economic importance, risk and impact.

ECONOMIC IMPORTANCE	RISK	IMPACT
Utilisation[5]	Electricity/Energy/Power[1]	Employment[12]
Investment[4]	Expertise & Technology[11]	Community[13]
Infrastructure[9]	Policy[3]	Environment[15]
Electricity/Power[1]	Availability[2]	Supply[10]
Income[6]	Geopolitical[8]	Demand[7]
	Labour[14]	

The first aspect of the category is factors of economic importance in the framework, namely power generation, investment, utilisation, income and infrastructure. Electricity is at the top of the list because energy is mostly required in all process of the economy.

The second aspect of the category is the factors of risk in the framework. In this regard, six risk factors have been identified. Energy is at the core of every growing and sustainable economy; therefore, any failure to provide reliable energy supply will result in a risk. South Africa is faced with the risk of electricity generation. This will continue to affect the economy and the country at large if the matter is not dealt with or a permanent solution has not been developed.

Minerals should be utilised with other alternatives in order to find a lasting solution for energy problems. These alternatives include renewable energy. Availability and supply risk affect utilisation of minerals. It is important that minerals are available and accessible. This poses a risk when the minerals are not available to be mined or the policy prohibits investment and mining.

The policy should also create a favourable environment for mining. Therefore, geopolitical factors remain a risk if the country is unstable. Furthermore, the absence of expertise and technology to mine the minerals poses a risk. In addition, labour cannot be ignored, as the mining operation may be interrupted by labour unrest. If the issue of labour is not dealt with in the framework, it holds a risk for mining.

The third aspect of the category is the factors affecting strategic and critical minerals due to their impacts on the economy and the country at large. The demand for utilisation of minerals in the domestic and international markets and adequate supply to the market have high impacts; if there is no demand, then there is no market for the minerals. A significant decrease in demand, especially when production is already at low capacity, is a risk.

It is important to have the market that will utilise the minerals which the country should supply. An additional factor that impacts the economy is unemployment.

The impact is huge, which automatically affects the community livelihood. The standard of living will be unaffordable for the citizens. Impacts of mining on the environment can also be devastating, therefore sustainability is important.

6.3. Criticality Matrix – risk, impact and importance of use of a mineral

Minerals are evaluated according to a criticality matrix using risk, impact and importance of use. Access and availability of reliable, consistent and unbiased data is important for the assessment of strategic and critical minerals. Minerals are plotted against importance of use and impact (represented on the vertical axis of the matrix) versus risk (horizontal axis of the matrix). The degree of strategic value and criticality of a mineral increases from origin of the figure as it is shown by the arrow and increased shading (see Figure 6.2). So, the combination of importance of use and availability risk will determine strategic and criticality of a specific mineral. Minerals in the red shaded block are strategically and critically important.

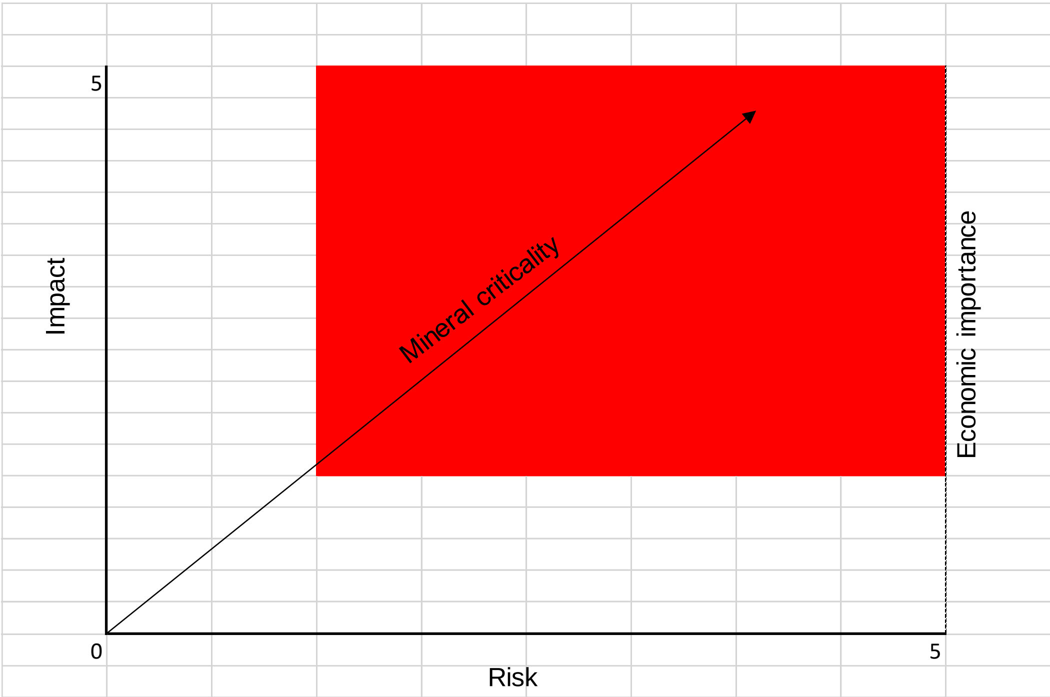


Figure 6.2: Criticality matrix overall plot of economic importance, impact and risk in the classification of strategic and critical minerals

The importance of use and impact of a mineral depends of the specific uses of a mineral. Possible substitutions of a mineral affect its importance of use, where substitutes are easily found the mineral will be less important. A mineral with no substitutes is highly important in use. The strategic and critical aspects of a mineral depend on time and is dynamic. It depends on changes due to technology advancements, environmental issues, policies and products required at a specific time. An example is the need for photovoltaic cells and rechargeable batteries during the electricity load-shedding crisis.

The risk of a mineral depends on the specific time of availability of a mineral (short, medium or long-term). It depends on whether the mineral resource exists, whether it can be produced in an environmentally and socially acceptable ways, whether government policies are conducive for availability to access, and whether the mineral is feasible and can be produced at a cost that users are willing and able to pay.

Parameters have been established in the study regarding a mineral's importance of use, impact and risk to apply the criticality matrix 26 minerals. Selected minerals considered were minerals used in large quantities in the economy according to their applications, minerals used in limited quantities in a small number of applications (e.g., emerging technology), minerals produced as by-products and minerals for which the industry is employing many people. In addition, a researched professional judgement was used to include some minerals that would be likely included in a list of potentially strategic and critical minerals. The study recognises that some minerals that may have not been considered could be considered strategic and critical depending on the application to a particular industry or application. A combination of quantitative measures and qualitative judgement is used in implementing the matrix methodology. Important information and data on the minerals including evaluation processes and screening is discussed in Chapters 2 and 4.

The parameters for risk, impact and economic importance including the arrows pointing to different parameters from economic importance and impact against the risk factor are shown in Table 6.2. The risks of electricity, expertise, technology and policy are related to the impacts of demand and supply. With regard to the economic importance, these risks are associated with income and power supply.

The arrows show that the risk of availability of strategic minerals, geopolitical factors and labour issues are related to the impacts of employment, community and environmental factors. As far as economic importance is concerned, these factors are associated with utilisation, investment and infrastructure.

The minerals that are mostly affected by parameters with high risk and impact to national security, essential function in manufacturing, time bound and for a specific purpose, and their absence result in serious consequences to the national security and economy are classified as critical. Critical minerals may not be strategic.

Strategic minerals are mostly those affecting national security, industrialisation, economic growth, employment, vital for applications in different uses, social and economic consequences and substitutes exists. Strategic minerals are always critical. They sustain modernised industry and are mostly affected by technology and substitutes. The time for strategic and critical minerals has arrived. There is a rise in demand for the critical minerals and any other mineral that is required in the energy transition including reduction of carbon emissions. Critical minerals play a major role in the transition from coal to renewable energy and a low-emissions economy. They dominated most of the deals activity in the Top 40's in 2022. Critical minerals of importance were mostly copper, lithium, nickel, cobalt, graphite, manganese, iron ore, aluminium and zinc (PWC, 2023).

Coal is not critical to South Africa due to its availability and supply risk status, but it is strategic to the country. The rise in demand made coal the biggest contributor to the Top 40's revenue for the first time in 2013 (PWC, 2023). This shows that coal has a role in the energy mix. A decline in coal demand may be expected in future.

In the criticality matrix, the methodology uses a relative scale of 0 (low) to 5 (high) to represent different degrees of importance or impact. The rating of 0 – 5 using the parameters is applied to classify the minerals as strategic and critical. Some minerals are more strategic and critical than others. Categories of importance of use, impact and availability or supply risk are considered in evaluating a mineral's criticality and the parameters are allocated and grouped in those categories (see Table 6.2).

Table 6.2: Factors (parameters) in the matrix plotting for Economic Importance vs Risk and Impact vs Risk

ECONOMIC IMPORTANCE	RISK	IMPACT
Utilisation[5]	Electricity[1]	Employment[12]
Investment[4]	Expertise & Technology[11]	Community[13]
Infrastructure[9]	Policy[3]	Environment[15]
Electricity/Power[1]	Availability[2]	Supply[10]
Income[6]	Geopolitical[8]	Demand[7]
	Labour[14]	

In order to determine the strategic importance and criticality of the mineral, the risk factors are calculated and plotted against the impact factors. The minerals with high risk and impact factors will be classified as strategic and critical according to their rating, where 0 – 1 is not strategic and critical, 1 – 3 is near strategic and critical; and 3 – 5 is strategic and critical as a reference from previous studies (see Figures 6.2 – 6.4). In this study, the parameters for the calculation of the risk factors are assigned relative weightings as follows: electricity (30%); expertise and technology (15%); policy (15%); availability (20%); geopolitical (10%); and labour (10%). The impact factors, on the other hand, are demand (30%); supply (20%); employment (20%); community (15%); and environment (15%). The importance of these factors is utilisation (30%), investment (25%), infrastructure (10%), and income (10%). Weightings for the parameters are assigned for each parameter as indicated in Section 2.5 and 4.3.1. The weight of each parameter is estimated based on the necessity and urgency of the factor required in order to mine or produce a mineral.

In the criticality matrix methodology, on the vertical axis, the degree of a mineral's importance may vary from one end use to another. Placing of a mineral on the vertical axis is time specific. Usage time period of a mineral affects mineral criticality. In addition, they key drivers of the minerals are their impact to nation's economy, importance to society and usage in new technologies. The placement of a mineral on a vertical axis after considering these factors represents the more researched professional judgement rather than quantitative analytical assessment. The quantitative assessment considered the mineral's proportional contribution to the market.

The scoring is semi-quantitative and attempting to weight the contribution and application for the mineral against the risk of mineral and identified parameters (see Appendix D). A mineral is plotted in a matrix according to the assessment of the assigned values from categories and weighted calculations of parameters (see Figure 6.2 - 6.4).

Mineral		**Utilisation**	**Investment**	**Infrastructure**	**Electricity**	**Income**
	Score	5	4	4	5	5
	Proportion	0.3	0.25	0.1	0.25	0.1
	Composite weighted Score	4.65				

South Africa is well positioned in the old Archaean cratons that contain different minerals of the world. The potential minerals have been identified that can be evaluated and classified as strategic and critical, as shown in Table 6.3. A proposed framework is put to use to analyse the minerals and classify them according to the assessment methods and according to their status for South Africa.

Table 6.3: Potential South African minerals

Potential Minerals				
Gold	Titanium	Limestone	Coal	Fluorspar
PGMs	Copper	Vermiculite	Vanadium	Silicon
Diamond	REE	Ilmenite	Iron ore	Zirconium
Silver	Uranium	Rutile	Nickel	Garnet
Chrome/chromium	Lead	Andalusite	Lithium	
Manganese	Zinc	Phosphate	Cobalt	Feldspar
Sulphur	Aggregate sand	Salt	Shales	Silica
Granite	Gypsum	Aluminium	Antimony	

Minerals are analysed using assessment methods according to the three categories of risk, impact, and importance of use to the country (see Figures 6.3 – 6.4). Classification of strategic minerals is subject to change for certain minerals depending on the availability of their substitutes and new improvements in technology that may render them useless for the country or its importance.

The US Net Import Reliance shows that South Africa is one of the major import sources of the following minerals: fluorspar, manganese, vanadium, gemstones, titanium mineral concentrates, chromium, diamond (industrial) stones, platinum, garnet (industrial), abrasives (crude silicon carbide), palladium, zirconium (ores and concentrates), and vermiculite. The country is the world's leading producer of chromium, manganese, palladium and platinum (USGS, 2022).

The potential strategic and critical minerals selected according to their economic importance of use such as future economy, energy, batteries and storage, manufacturing, risk of supply, impact to the national economy, competitive advantage due to abundance including opportunities of hydrogen economy are rare earth elements, vanadium, manganese, zinc, chrome, lead, copper, iron ore, PGMs, coal, uranium, nickel, fluorspar, lithium, cobalt, zirconium, gold and diamond.

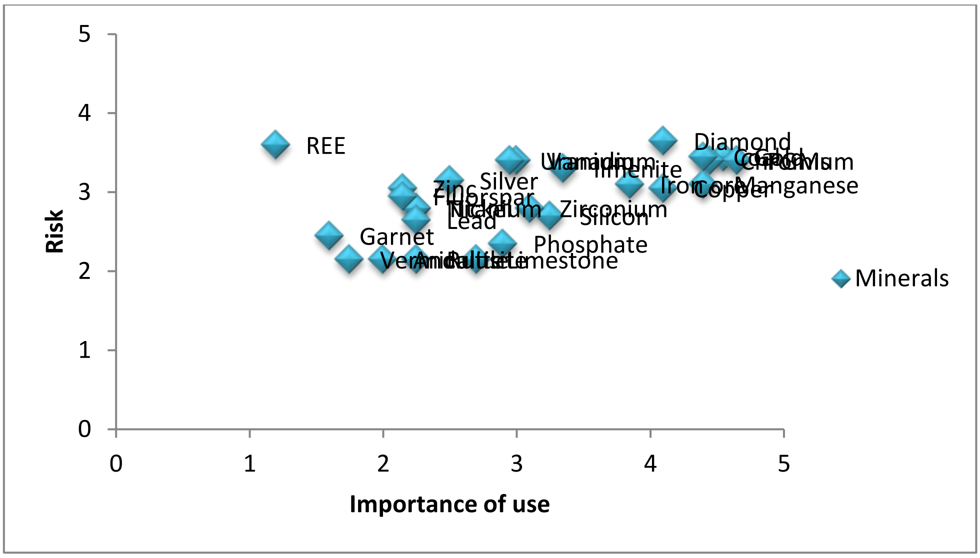


Figure 6.3: Criticality matrix plot of risk versus economic importance in the classification of strategic and critical minerals.

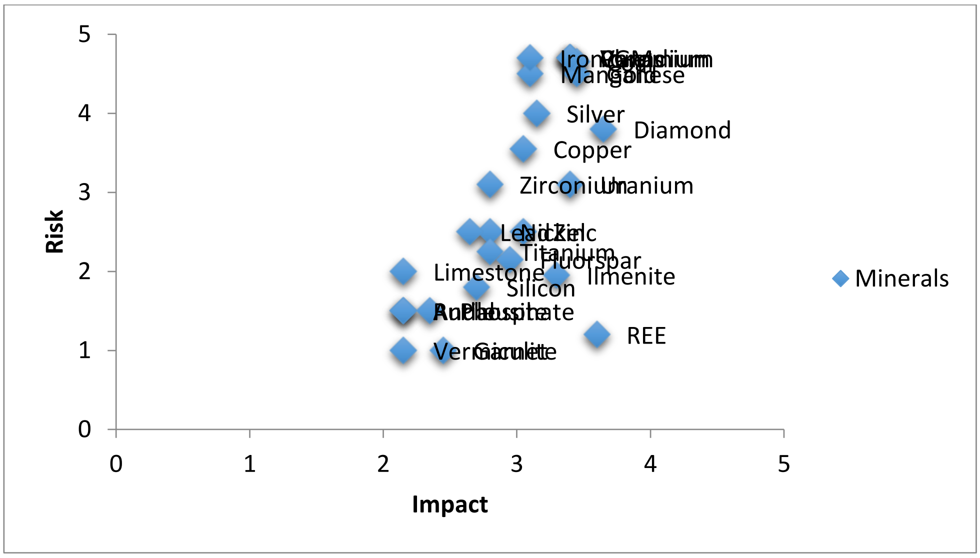


Figure 6.4: Criticality matrix plot of risk versus impact in the classification of strategic and critical minerals.

Strategic minerals are needed to sustain modernised industry. Their supply is also subject to any time restriction depending on their important uses and vulnerability (impact and risk). The following fifteen factors pertinent to the country's situation have been identified: electricity (power), supply, demand, availability, utilisation, geopolitical risks, income, employment, community, expertise and technology, investment, policy, labour, environment, and infrastructure. The risk versus impact and risk versus importance of use result in the following strategic and critical minerals of South Africa (see Figure 6.5):

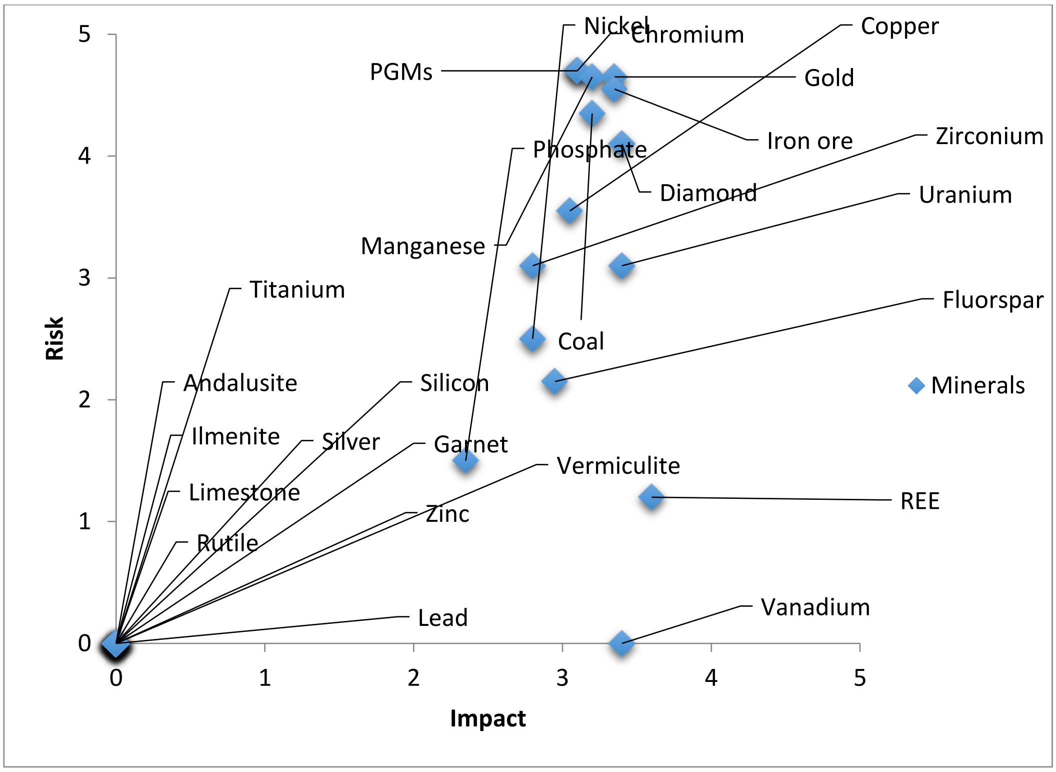


Figure 6.5: Criticality matrix plot of risk versus impact in the classification of strategic and critical minerals

Strategic minerals are needed to sustain modernised industries such as manufacturing, technology and health. Their supply is subject to any time restriction depending on their important uses and vulnerability (impact and risk). The identified fifteen factors pertinent to the country's situation (electricity (power), supply, demand, availability, utilisation, geopolitical risks, income, employment, community, expertise and technology, investment, policy, labour, environment and infrastructure) were applied in the criticality matrix methodology to obtain the composite weighted score. The risk versus impact and risk versus importance of use result in the following strategic and critical minerals of South Africa (see Table 6.4).

Table 6.4: Classified strategic and critical minerals (highlighted in grey)

Potential Minerals				
Gold	Titanium	Limestone	Coal	Fluorspar
PGMs	Copper	Vermiculite	Vanadium	Silicon
Diamond	REE	Ilmenite	Iron ore	Zirconium
Silver	Uranium	Rutile	Nickel	Garnet
Chrome	Lead	Andalusite	Lithium	
Manganese	Zinc	Phosphate	Cobalt	Feldspar
Sulphur	Aggregate sand	Salt	Shales	Silica
Granite	Gypsum	Aluminium	Antimony	

Minerals remain significant contributors to the economy in terms of employment numbers, export earnings, royalties as well as attracting foreign direct investment. In 2021, the mining industry accounted for about 458,954 people employed, employee earnings of R153.8 billion, pay as you earn tax by mining employees of R270.0 billion, value added tax refunds of R50.4 billion, value added taxes paid of R15.4 billion and direct Gross Domestic Product (GDP) contribution of R480.9 billion.

In addition, the sector contributed 8.7% to the country's GDP, attracted over R841 billion export sales, contributed R849.6 billion total primary sales, R78.1 billion in corporate taxes and R27.9 billion in royalties (MCSA, 2021).

Significant contribution to the economy and national security of the country is from the selected strategic and critical minerals. The four major contributors to the total mining value-add to the economy of the country are coal, platinum group metals, gold and iron ore. In addition, these minerals are followed by three selected minerals, namely, chrome, manganese, and diamonds. Other important strategic and critical minerals are copper, cobalt, vanadium, nickel, zinc, lead, uranium, rare earths elements, lithium, fluorspar and zirconium. Their contribution is also important to the socio-economic input to the employment of the citizens.

CHAPTER 7: OVERALL CLASSIFICATION FRAMEWORK AND SOCIO-ECONOMIC IMPACTS

7.1. Framework

The framework utilised qualitative assessment and was supported by quantitative analyses of data. Selected assessment methods of strategic and critical minerals were considered to develop a framework to classify and compile a list of strategic and critical minerals for the country.

Several approaches by different countries are used to assess strategic and critical minerals such as NRC and the US NSTC. Other European countries such as France, Finland, the Netherlands, Sweden, and the United Kingdom embarked on studies to identify minerals that are important to their economy and developed plans to ensure security of supply. The frameworks provide understanding of the country's vulnerabilities and opportunities for policy interventions (EU, 2014).

Minerals contribute to the economy of the country. Potential minerals have been identified (as input) in the development of the framework. These minerals are evaluated and ranked according to three categories, namely economic importance, risk and impact. Outcomes from the evaluation and ranking (as output) of potential minerals result in the classification of strategic and critical minerals. The developed framework promotes increased economic use, reduced risk, and regulates the impact of minerals classified as strategic and critical to the country (see Figure 7.1).

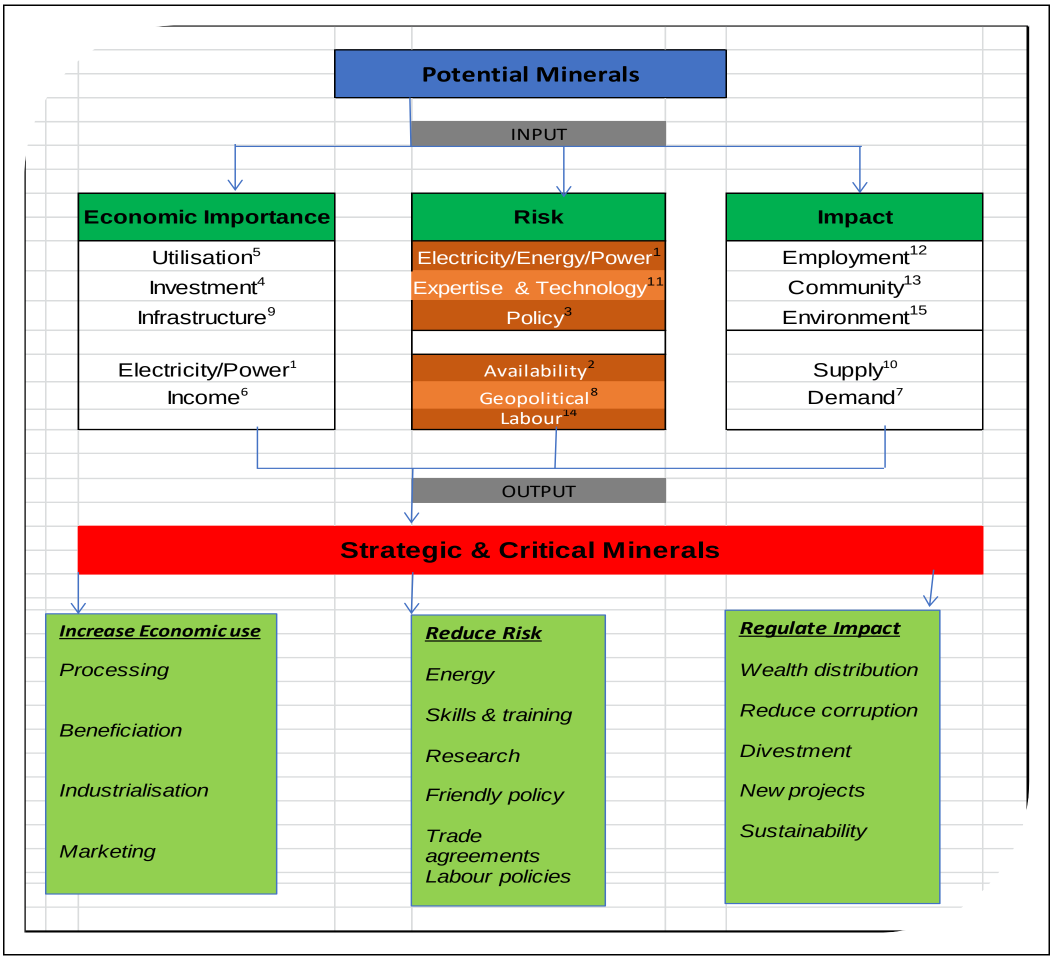


Figure 7.1: Framework for strategic and critical minerals

7.2. Potential minerals

The assessment methods for strategic and critical minerals in the developed countries (e.g., US, EU) were used to evaluate and rank South African minerals as strategic and critical to their country. In addition to the established methods, minerals were analysed according to the fifteen parameters in the South African context to determine its strategical and criticality status.

The assessment was based on identifying the mineral status, identifying its application (importance of use), identifying any readily available valid substitutes or related problems (risk) such as mineability, potential disruptions, reliance of foreign markets/investments, labour strife and disputes; and assessing the impact thereof in the country.

Electricity is one of the identified parameters and poses a major risk in the development and growth of the mining industry. It is important that low-cost energy sources and affordable labour costs increase production and growth in the framework. Higher energy costs hamper growth in the mining industry. A good energy mix is necessary which include nuclear and renewable energy. The country's power utility has fifteen coal-powered stations in which their life span may be extended to 2050. There is infrastructure and capacity to utilise the coal resources and reserves in the country. An energy plan in the country should include coal as part of the solution to the energy crisis experienced in South Africa.

Perceptions from the local communities about the impact of mining operations in their community show that the local communities misunderstand the responsibilities of the mines and government and have unfulfilled expectations. Most respondents that completed the survey questionnaire are from Gauteng and North-West. Normally most of the protest actions and court battles with the community/royal families or mining companies are experienced in these areas. This is an indication that the community is aware of mining companies in their area and have developed expectations as a result of the mining.

The mining industry employs mostly males due to the labour-intensive activities of the mine. Other contributing factors may be the remote location of the mines and the career options chosen by the females. The young people showed a lot of interest, and they were mostly available during the study. The availability of young people during the survey is also probably due to the high rate of employment in those communities.

The majority of young people have completed secondary schooling as their highest level of education. The highly educated community members may have left the rural and township areas for the urban towns and cities.

The mines will also employ a few highly educated members of the community. According to the study, local community members are normally members of big families, as it had been observed that a household has between two to six people. The majority of the participants are breadwinners that take care of the families, and these are usually not the highly educated members in the family.

The study further showed that there may be a lack of entrepreneurship in the community, as only a few people (3.2%) derive their source of income from their own business. The majority of the respondents depend on a salary and do not own a business. The social grants are the second source of income. Employment experience of one to four years is within the training, internship and apprenticeship, which were higher, more than half of the five to ten years' experience. A small percentage had more than eleven years' experience. The majority of people are permanently employed, which firstly confirms that they depend on a salary, and secondly, that they may have a lack of entrepreneurship. Most members of the workforce are employees and not managers, as expected in the mining area that requires more unskilled labour.

Perceptions with regard to the positive impacts of mining vary across the respondents. General concerns are an increase in the standard of living, diseases that affect the quality of life, and new behaviours in the community. The increase in employment is not as high as expected, because most respondents complained at the time of the survey that the mines employ more outsiders than local members. The respondents were not convinced that the new business opportunities were positive, because most opportunities were given to people outside their community. Local members were mostly excluded from major contracts due to capital, expertise and experience required for the services at the mine.

The community has a strong perception that there are more tradesmen because the mines are offering their employees training and skills development, including people in the community who never worked at the mines. This is a real concern, as they believe that most of the people are not from their local community.

The impacts of mining in the community are perceived negatively. Many people are concerned about the increased migration of labour from other areas into their community due to employment from the mines. This confirms the perception that mining companies employ people from outside their community. There is a low perception on the negative impacts of mining activities on the environment. Mining companies provide water to some communities, especially to informal settlements. For this reason, most of the people do not have concerns about the negative impacts of mining on the water in their community. However, local people are aware of the negative impacts of mining with regard to land availability because some of them are crowded in the townships and informal settlements closer to the mining lease area. High levels of crime in the communities are perceived to be due to the mines operating in the area. Teenage pregnancies are associated with the mines in the area. The perception is that mining employees impregnate young girls in the community.

Mining operations are mostly located in remote areas. Communities have a tendency to relocate and build houses close (approximately 20 – 50 km) to the mines. Sometimes the mining companies will build houses for their own employees. Many informal settlements can be seen close (approximately 5 -15 km) to the mining operations; therefore, the perceptions of local community members are important to understand the impacts of mining in the area.

Mining companies are building houses for their employees, but some of employees are not aware because the houses have not been allocated to them yet. The main problem highlighted by the survey was the illegal occupation of these houses by other members of the community who do not work for the mines.

The framework ensures that the minerals are optimally used and benefits all in the country. According to the local residents the communities in the neighbouring mines do not benefit from the mining operations. These communities are affected by the impacts of mining operations. Perceptions of the local communities on the socio-economic impacts of mining on their community cannot be ignored. Minerals that are considered strategic and critical should benefit local communities and the country at large to avoid a resource curse, that is, the minerals are there, but it is of no benefit to the community.

7.3. Strategic and critical minerals

Minerals identified and evaluated in the framework are classified as strategic and critical. The framework strives for a balance between imports and exports and avoid placing minerals at risk or vulnerable to benefit South Africa. Utilisation of minerals support the objectives, plans and vision of the NDP, including the implementation of the strategic value chains of the ministry of mineral resources and energy.

The country benefits from minerals and materials exported outside the country. High volumes of production at low prices in the market pose a risk to the economic viability of the mineral. The developed framework promotes domestic utilisation of the identified minerals. High utilisation and increased domestic mineral beneficiation capability are important to balance exports of domestically mined raw material.

Industrialisation promotes high utilisation, therefore, when locating power stations, manufacturing and beneficiation plants, the country should consider production concentration of mines and commodities, reserve distribution, recycling rate, substitutability, rail and road infrastructure, labour and management. In addition, demand growth; demand risks (i.e., pricing, recycling and substitution); structural or technical scarcity; importance of use; lack of suitable technologies; and infrastructure and pricing incentive are important in the classification of strategic and critical minerals.

The industrial demand in mineral-rich countries is mostly lower than the available supplies. South Africa experiences the same challenge and should develop steps to reduce export dependence through beneficiation, industrialisation and internal use. Thirty-eight minerals were screened, 18 potential minerals identified and most seven selected as strategic and critical according to economic importance, risk and impact factors. The developed list of strategic and critical minerals is subjective, therefore it depends on who asks whether minerals are strategic or critical to the country or manufacturer, as well as the parameters applied in the assessment. A mineral ceases to be critical when the country meets its needs for that mineral through domestic mining and processing. Criticality is not constant; it changes over time due to evolving technological developments and material demands. Therefore, a mineral must be available in time when required at an acceptable cost to meet the demand for current and emerging products and technologies.

7.4. Socio-economic impacts

The local communities, employment and environmental aspects are equally important socio-economic impacts in the overall framework. During mining activities, the environment and people are affected by several factors, such as dust noise, excavations, and water and land availability for other uses like agriculture.

When the mining industry experiences challenges, local communities always suffer due to restructuring, asset consolidation initiatives, closure of marginal mines, and reduced employment numbers.

Some of the minerals mined are exported internationally to be used to keep the environment and air of major global cities clean; however, these mined minerals leave the air and environment of local communities unclean and disturbed. The mines will mostly leave the environment degraded and in a messy situation, while taking the profits outside the country. The mining towns are normally left as ghost towns when mining operations close down. The requirements of the social and labour plan and mining charter III should therefore be implemented, and additional offerings from the mining houses will ensure sustainability after the mining activities.

7.5. Concluding remarks

The framework for the classification of strategic and critical minerals is composed of the inputs, screening and assessment methodology, leading to the output of classified minerals considering their contribution in the country and socio-economic impacts in the community.

Potential minerals are identified during the exploration stage. These minerals are evaluated through several stages of classification (see Section 4.3.2) specific to the country. Selected minerals that have been screened are subjected to the assessment criteria (see Section 6.3). The minerals are assessed according to their risk, impact and economic importance to the country. Outcomes of the assessment methodology result in strategic and critical minerals that can strategically position the country in the world.

The framework promotes an increase of the economic use of minerals through processing, beneficiation, industrialisation, and marketing. In addition, the framework reduces the risk associated with the mining industry by providing adequate energy, skills and training, research, a friendly mineral policy, trade agreements, and labour policies. Finally, the framework regulates the impact of mining in the country by ensuring wealth distribution, new projects, and sustainability, and reducing corruption and divestment.

Communities in the vicinity of mining operations are affected socially, economically and environmentally. The impact of mining in the framework is addressed in collaboration with community consultations. Local communities should benefit from the proceeds of mining and should be educated about the value chain of mining in order to avoid conflicts and misunderstandings.

CHAPTER 8: CONCLUSION

8.1. South African advantages and challenges

The government of South Africa is the custodian of the mineral resources in the country. Different departments such as DMRE, CGS, DST, NT, and StatsSA as well as private institutions such as MCSA and consulting firms play a major role in collating information to monitor strategic and critical resources, domestic utilisation and demands from global markets, as well as their related changes and trends.

South Africa is endowed with mineral deposits and has a comparative advantage. Mining continues to contribute to improve the quality of life and the economy of the country. Well-managed mineral resources can benefit the community and should not become a curse. Most of the minerals in South Africa are exported as raw materials once they are produced, and final products are sold back to the country. There is also a high rate of unemployment, poverty and inequality. Therefore, trade-offs should be considered in mineral beneficiation which can contribute towards industrialisation.

8.2. Overview of the study

It is noted in the study that all minerals could be strategic and critical to some degree depending on their importance of use and availability risk. Strategic and criticality of the mineral may change due to new technologies, substitution or when new products are developed.

The study focused on a short-term aspect of the strategic and critical minerals. Current challenges to the South African context were considered in the classification framework of the minerals.

Limitations of the framework are the updating of the data and information on a regular basis, complexity of the model employed, lack of necessary data, limited resources needed for collection of certain data and updates and short-term focus on the strategic and criticality aspects of the minerals.

The supply and demand of strategic and critical minerals depend on the needs and requirements of the market, producers, consumers, investors, shareholders, communities, employees, employers and the government.

When managed properly, minerals can benefit society. Market forces such as demand and supply alone cannot provide control and optimal utilisation of strategic mineral supplies. Some form of action by the government is required to meet shortfalls and contingencies. The framework of the classification of strategic and critical minerals is used to develop a list of strategic and critical minerals for the country, which assist in developing strategies to reduce reliance on export markets and actions to support domestic utilisation of minerals to promote industrialisation. Parameters used to develop the framework are electricity, supply and demand, availability, utilisation, geopolitical risks, income, employment, community, technology (expertise and machinery), investment (capital), policy, labour, environment and infrastructure.

Systems are proposed in the framework (Section 7.1) to ensure that new resources are identified and explored, as well as promotion of favourable policies for the mining environment. Activities should be increased at all levels of the value chain, such as exploration, mining, processing, beneficiation, which include recycling and reprocessing of the minerals.

The strategic and critical minerals and major contributors to the economy include coal, platinum group minerals, and gold. The South African mining industry is experiencing main challenges related to expertise (know-how and specialised skills), machinery (equipment and technology), labour (costs and strife), low-market demand, industrialisation and investment (capital). Despite these challenges, there are major socio-economic contributions from the industry such as employment (i.e., jobs), GDP, foreign exchange, investment, foreign savings, corporate tax, royalties, operational and capital expenditures, wages and salaries, Transnet's rail and port, electricity generation, and electricity demand (consumption) and liquid fuels. The South African economy will therefore benefit from mineral resources that have been declared strategic and critical, thus enhancing the economic and strategic position of the country.

Modernisation of mines in the country can result in the implementation of technology and innovation initiatives which will lead to upskilling of the employees. Upskilling will lead to improved safety and more skilled workers, which will contribute towards lower extraction costs, and improved competitiveness to other producers and suppliers.

Employees and community members are concerned about the technology and innovation in the mining industry. Perceptions about the socio-economic impacts of mining in the local community have indicated that communities are aware of mining activities. Communities are aware of the mines' contribution, such as revenues to central government, payment of royalties, traditional authorities and local councils, landlords, as well as social facilities (such as schools, hospitals, health services, water, and scholarship schemes). Some of these contributions do not reach the community and are not communicated clearly in the stakeholder's meetings.

It is further noted that communities could not divide/classify the responsibilities of the mine into central, provincial, local governments, and local municipalities. Communities mostly compare themselves with other municipal areas where mines are operating, and the particular communities in those municipality areas receive the best services.

The problem of a low educational and skills level of local communities is a barrier to finding employment in the mines and local economic sectors, including the government to sustain infrastructural development, parastatal organisations, as well as water supply, road and telecommunications facilities.

Expectations of increased employment and quality life in the community due to mining operations are often not met. There is also a gap between the expected benefits for the local community and what the mines are actually doing for the community. The mining companies should therefore establish effective regular community and stakeholder consultation meetings directly with the community to ensure flow of information and transparency. These meetings will also address the misconceptions that communities have about the mine. Communities indicated that mining companies target the community leaders, councillors, trade union leaders, and their families and relatives for the maximum benefits from the mine to silence the community and camouflage the assistance from the mine to the community.

There will be dire direct and indirect socio-economic impacts on employment if mining has to be discontinued. Statistics on the contribution of mining to employment and results of the community survey have confirmed that mining is important for the economy and society.

8.3. Contribution of the study

The study has developed a framework that can be used to classify strategic and critical minerals in South Africa. A proposed framework will assist, support and complement the beneficiation strategy as well as the achievement of the National Development Plan objectives. Strategic and critical minerals will promote industrialisation in the country to address the threefold problem of poverty, unemployment and inequality in the country.

In addition, perceptions of the local communities about the impacts of mining in their area have been established. A gap exists between the expected benefits of the local community and what the mines are actually doing for the community, as reported in the social and labour plan including reporting on the corporate social responsibility.

8.4. Recommendations and future work

The study will be further enhanced by researching and comparing the social labour plan commitments from the mines, as well corporate social investment reporting in the annual reports against the actual delivered and completed projects in the community. Strategic teams must also be formed to focus on specific minerals in order to gather information and data specific to the minerals to assess minerals in the framework. Additional work requires a survey of regulators, law makers, producers and manufactures for their inputs in strategic and critical minerals including a detailed quantitative methodology for assessment of strategic and critical minerals.

Further, water resource is critical in the mining operations. Therefore, a further study should be conducted that considers the impact of the risks due to any disruption and lack of water on the mines, including manufacturing and beneficiation plants.

Moreover, coal mining is under pressure as a result of environmental requirements and climate change. Therefore, a research study focused on clean coal technologies will reposition coal in the economy of South Africa. In addition, a study on cheaper energy sources, low labour costs, as well as infrastructure and capacity in the country will assist in strategically positioning the mining industry in the country.

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APPENDICES

APPENDIX A: QUESTIONNAIRE

The survey questionnaire designed and distributed to participants in the local community around the mining operations.

QUESTIONNAIRE

PERCEPTIONS OF LOCAL COMMUNITIES ON THE SOCIO-ECONOMIC IMPACTS OF MINING.

The objective of this research study is to assess local communities' perceptions of the socio-economic impacts of mining.

A questionnaire is divided into the following sections:

Section 1 Personal characteristics

Section 2 Employment and economic activities

Section 3 Community projects and environment

Section 4 Settlement

The study is interested in the perceptions of communities living around the mines about the socio-economic impacts of mining. Please read each question carefully and answer it to the best of your ability and knowledge.

Many questions in this survey are close-ended, requiring you to **mark (with an "X")** the option that best describes you, your understanding and experiences. It will take you about 20 minutes to complete this questionnaire.

SECTION 1: PERSONAL CHARACTERISTICS

1. Indicate the geographical location (Region/Province) of your community.

Gauteng	North-West	Limpopo	Mpumalanga

2. Indicate your gender.

Male	Female

3. Indicate your age on your last birthday.

< 21 years	21 -30 years	31 - 40 years	41 - 50 years	51 - 60 years	> 60 years

4. Indicate the highest level of education you completed.

Did not attend school	Primary school	Secondary school	University/ Tertiary education

5. Indicate the total number of your household members and dependents.

1 person	2 – 3 people	4 – 5 people	> 6 people

6. Indicate your relationship in the household.

Bread-winner	Spouse	Son/Daughter	Other:

7. Indicate your household's main source of income.

Salary	Own business	Social grants	Other:

SECTION 2: EMPLOYMENT AND ECONOMIC ACTIVITIES

8. Indicate your employment status:

a.	Where do you work?	Mining		Other:		Unemployed
b.	How many years/months have you worked in this job?	< 1 year	1-4 years	5-10 years	> 11 years	Unemployed
c.	What is your current work status?	Permanent	Contract	Part-time		Unemployed
d.	What is your position at work?	Employee	Supervisor	Manager	Director	Unemployed

9. Indicate the level at which the following has benefited (**positive impacts)** your community because of the mining operations – where **(1)** is "extremely **low**" and **(5)** "extremely **high**".

POSITIVE IMPACTS		**Low**			**High**	
a.	Improved quality of life	1	2	3	4	5
b.	Increased employment (i.e. more jobs) in the community	1	2	3	4	5
c.	New business opportunities in the area	1	2	3	4	5
d.	More tradesmen in the area	1	2	3	4	5
e.	Training to work in the mines and improvement in skills	1	2	3	4	5
f.	Increased employment from indirect mining related company	1	2	3	4	5

g. Other positive impacts:…………………………………………………………...

10. Indicate the level at which the following has **negatively impacted** your community because of the mining operations – where **(1)** is "extremely **low**" and **(5)** "extremely **high**".

NEGATIVE IMPACTS		**Low**			**High**	
a.	Increased migration of labour	1	2	3	4	5
b.	Environmental conditions (management, minimisation, disposal, recycling, littering)	1	2	3	4	5
c.	Water (quality, reduction, contamination, management)	1	2	3	4	5
d.	Land availability (conflicts, occupation)	1	2	3	4	5
e	High crime levels	1	2	3	4	5
f.	Abuse of drugs and alcohol	1	2	3	4	5
g.	Teenage pregnancy	1	2	3	4	5

h. Other negative impacts:…………………………………………………………...

SECTION 3: COMMUNITY PROJECTS AND ENVIRONMENT

11. Indicate whether the following projects or improvements were experienced in your community because of the mines in your area.

a.	Newly built and improved roads	Yes	No
b.	New recreational facilities (sports ground, parks, etc)	Yes	No
c.	New clinics	Yes	No
d.	Government policies are driving improvements in the area	Yes	No
e.	Improved social status (Corporate Social Responsibility)	Yes	No

12. Indicate the level at which the following has benefited (**positive impacts)** your community because of the mining operations – where **(1)** is "extremely **low**" and **(5)** "extremely **high**".

POSITIVE IMPACTS		**Low**			**High**	
a.	Improved health services	1	2	3	4	5
b.	Educational facilities	1	2	3	4	5
c.	Bursaries and scholarships	1	2	3	4	5

d. Other positive impacts:…………………………………………………………...

13. Indicate the level at which the following has **negatively impacted** your community because of the mining operations – where **(1)** is "extremely low" and **(5)** "extremely high".

NEGATIVE IMPACTS		**Low**			**High**	
a.	Pollution (Dust, noise, waste, water)	1	2	3	4	5
b.	Community strikes or protests	1	2	3	4	5
c.	Damaged houses	1	2	3	4	5
d.	Labour/ Union strike impact on work function	1	2	3	4	5

e. Other negative impacts:………………………………………………………………...

SECTION 4: SETTLEMENT

14. Indicate your status of settlement in the area:

a.	Where do you stay?	Town	Township	Rural	Informal
b.	How many years/months have you been living in this community?	< 1 year	1-4 years	5-10 years	> 11 years
c.	Have you been displaced from where you used to live before because of the mine?	Yes		No	
d.	Were you compensated?	Yes		No	

15. Indicate the level at which the following has benefited (**positive impacts)** your community because of the mining operations – where **(1)** is "extremely **low**" and **(5)** "extremely **high**".

POSITIVE IMPACTS		**Low**			**High**	
a.	Resettlement to better areas	1	2	3	4	5
b.	Adequate compensation for displacement	1	2	3	4	5
c.	Adequate schools have been built	1	2	3	4	5
d.	Adequate houses have been built	1	2	3	4	5

e. Other positive impacts:…………………………………………………………………...

16. Indicate the level at which the following has **negatively impacted** your community because of the mining operations – where **(1)** is "extremely **low**" and **(5)** "extremely **high**".

NEGATIVE IMPACTS		**Low**			**High**	
a.	Increased informal settlement	1	2	3	4	5
b.	Higher rental and house prices	1	2	3	4	5
c.	Increased population	1	2	3	4	5
d.	Inadequate infrastructure and poor services	1	2	3	4	5

e. Other negative impacts:…………………………………………………………………...

APPENDIX B: FACTORS

The **three factors** (i.e., economic, risk and impact) used in the classification of strategic and critical minerals.

a. *__Economic use__* may be increased by processing and beneficiation, industrialization and marketing.

b. *__Risk__* may be reduced by providing stable energy, skills and training, friendly policy, trade agreements, labour policies and *conduct exploration.*

c. *__Impact__ can be regulated by proper distribution of wealth, reduce corruption, divestment, new projects and sustainability.*

<u>ECONOMIC IMPORTANCE</u>
Utilisation 5 - end use sectors and their contributions
Investment 4 - contribution to the GDP
Infrastructure 9 - adequate infrastrure,
Electricity/Power 1 - importance of electricity to the mining of that mineral
Income 6 - Total income that the mineral is bringing to the country
How to increase the economic use = processing and beneficiation, industrialisation, marketing
<u>RISK</u>
Electricity/Energy/Power 1 - what will happen if there is no electricity
Expertise & Technology 11 - what will happen if there is disruption of expertise & technology, do we secured supply
Policy3 - are the policies attracting or impeding the mining of the mineral
Availability2 - is the mineral available, if not what then? Depletion of reserves?
Geopolitical8 - global politics effects on the mineral
Labour14 - effects of labour unrest on the mining of the mineral
How to reduce risk = provide energy, skills and training, research, friendly policy, trade agreements, labour policies, exploration.
<u>IMPACT</u>
Employment12 - number of jobs created, number of jobs will lose
Community13 - improvement in the community, downturn on the community if no mining of that mineral
<u>Environment15</u> - up and downside of mining on the environment, the use or abuse on the environment versus the importance
Supply10 - availability of the mineral, infrastructure, production,
Demand7 - market, substitution and recycling
How to regulate the impact = proper distribution of wealth, reduce corruption, divestment, new projects & sustainability

APPENDIX C: DATA NEEDS

The following departments and institutions are identified to provide relevant information and data required to evaluate the factors affecting the strategic and critical minerals.

Importance of use	Formula	Source	Indicator	Description	Rating
Utilisation		statssa,mcsa,treasury		consumption, end-user, exports, imports	
Investment		treasury, statssa, mcsa		Value-add	
Infrastructure		ndp,dept,		sufficient, developed	
Electricity		eskom,cgs		power, supply, consumption	
Income		statssa,mcsa,treasury		gdp, figures	
Risk	**Formula**	**Source**	**Indicator**	**Description**	**Rating**
Electricity		eskom,cgs, mc,		loadshedding, consumption	
E & T		dept labour, critical skills, OEM		availability of equipment,persons,skill	
Policy		dmre		clarity,info availability,	
Availability		cgs,reserves,resources,samrec,samval		minerals,land,community,location/depth, substitution	
Geopolitical	RF = (S + LE + SP) + 2 x (MS + R + WP),	wgi		community,unrest,location,	
Labour		dept labour, critical skills,		local,foreign,protests,	
Impact	**Formula**	**Source**	**Indicator**	**Description**	**Rating**
Demand		exports,statssa		buyers/global consumption	
Supply		statssa		production/depth/	
Employment		statssa		locals/contribution, unemployment	
Community		statssa		land/social,economic,health	
Environment		statssa,locals		pollution, waste, water,	

APPENDIX D: CRITERIA

Sources of information to be used in the assessment of strategic and critical minerals.

	CRITERIA - SOURCE	IMPORTANCE OF USE
Utilisation	Global & local demand; internal & external usage; production Applications; beneficiation & industrialisation	
Investment	Expenditure; GDP; Capital Economic contribution	
Infrastructure	Adequacy - Current & required; Road; rail; port	
Electricity	Level of requirement (mining, manufacturing, etc); power generation; renewables; pricing; reliable supply	
Income	GDP; Sales	

<5	<500	1
5_9	500 - 999	2
10_29	1000 - 2999	3
30 -49	3000 - 4999	4
>50	>5000	5

Income - mineral sales		
<1	<1bn	1
1_4	1bn - 4bn	2
5_19	5bn - 19bn	3
20 -100	20bn - 100bn	4
>100	>100bn	5

	CRITERIA - SOURCE	RISK
Availability	Reserves -World ranking; Exploration; Substitutes	
E & T	Machines; Opportunities(e.g. Hydrogen economy) Modernisation; technological changes	
Policy	Adequacy - Current & required; Health & Safety Regulation	
Electricity	Level of requirement (mining, manufacturing, etc);	
Geopolitics	Locality of major reserves - ranking; Warpact; Infrastructure World Governance Index (WGI)	
Labour	Cost; Employee earnings; Injuries	

Risk	Availability -Rank & Reserves		
<5	<100kt	5	>R15
5_9	100kt - 199kt	4	>R12 - R15
10_29	200kt - 299kt	3	>R6 - R12
30 -49	300kt - 5mt	2	>R3 - R6
>50	>6mt	1	<R3

Geopolitics			
Locality of major reserves			
<1m	<0.5m	5	>R15
10_69	0.6m - 2m	4	>R12 - R15
70_99	3m - 4m	3	>R6 - R12
100 -299	5m - 7m	2	>R3 - R6
>300	>8m	1	<R3

Labour		
Employee earnings		
<3	<3bn	1
3_6	3 - <6bn	2
6_9	6 - <9bn	3
9_12	9 - 12bn	4
>12	>12bn	5

	CRITERIA - SOURCE	IMPACT
Demand	Sales demand; internal & external usage; production Manufacturing sectors	
Supply	Global & Local demand; internal & external usage; production; Price & market; consumption	
Employment	Jobs; GDP; Training	
Community	Adequacy - Current & required;	
Environment	Level of requirement (mining, manufacturing, etc); ESG; Climate change; Health	

<5	<500	1
5_9	500 - 999	2
10_29	1000 - 2999	3
30 -49	3000 - 4999	4
>50	>5000	5

Demand - Sales

<1	<1bn	1
1_4	1bn - 4bn	2
5_19	5bn - 19bn	3
20 -100	20bn - 100	4
>100	>100bn	5

Employment numbers

<1m	<5k	1
10_69	5k - 8999	2
70_99	9k - 14999	3
100 -299	15k - 2999	4
>300	>30k	5

Supply - Production & reserves

<1	<10k	1
10_69	10k - 19.99k	2
70_99	20k - 29.99k	3
100 -299	30k - 8.99m	4
>300	>9m	5

Royalties - Paid

<1m	<30m	1
10_69	30m - <600m	2
70_99	600m - <900m	3
100 -299	900m - <1.0bn	4
>300	>1.0bn	5

Impact — Availability -Rank & Reserves

<1000t	1	>R13
1kt - 299kt	2	R13 - R15
3kt - 1mt	3	R7 - R12
2mt - 5mt	4	R4 - R6
>6mt	5	<R3