Towards a critical minerals strategy for South Africa

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Abstract

The global transition towards renewable energy and advanced battery technologies has increased demand for critical minerals, necessitating strategic mineral resources management. South Africa, endowed with vast mineral wealth, has yet to formalise its critical minerals strategy (CMS) to align with global best practices and secure its position in the changing minerals economy. This study explores the foundational elements required to develop a CMS by analysing established strategies from leading mining economies which are the United States, Australia, Canada, the United Kingdom and India, and assessing their applicability to the South African context.

Using a qualitative case study research approach, this research examined critical mineral policies, regulatory frameworks, stakeholder relations, and supply chain strategies across these case study nations. The findings highlight key themes, including, national security, supply chain diversification, sustainability, stakeholder collaboration, and technological innovation, all of which are important for a robust but dynamic CMS. The study also covered South Africa's opportunities and challenges, emphasising the need for policy coherence, investment in research and development, mineral exploration and infrastructure development.

The paper concludes with recommendations for South Africa's CMS discussing elements that can leverage South Africa's mineral resources for economic transformation, industrial development and global competitiveness. This study contributes to academic discourse on resource governance by providing a structured framework for emerging economies to navigate the critical minerals development in a rapidly evolving geopolitical landscape.

Keywords: South Africa, Critical Minerals Strategy, Economic Development, Environmental, Social and Governance, Exploration, Beneficiation, Technology.

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CHAPTER 1. INTRODUCTION

1.1 Statement of purpose

This study explored the foundational steps required to establish a comprehensive critical minerals strategy (CMS) for South Africa. The aim is to identify the best global practices in formulation of CMS and assess their applicability and practicality in the South African context.

1.2 Background of the study

South Africa's mining sector, which has a rich and diverse history, plays a significant role in its economic development. At the time of writing, the country had already developed a significant number of policies to enhance the mining of minerals to be sold for various purposes both internally and to external markets (Government of South Africa, 2024). South Africa is also a source of numerous minerals – widely known as critical minerals – that are essential to future-facing markets, including copper, nickel, lithium, rare-earth metals, graphite and cobalt. All are widely valued for substantial contributions to their respective industries (DMRE, 2022),such as the green technologies, electronics, defence and renewable energy sectors, and have become pivotal for steering the world toward a sustainable future (Africa Natural Resources Management and Investment Centre (ANRC), 2022).

However, despite being endowed with a wide range of minerals and policies to regulate them, South Africa is yet to formalise a strategy focused on critical minerals essential for modern technologies and a green economy (Government of South Africa, 2024), despite Barteková and Kemp (2016) arguing that a formalised CMS is essential for guiding policy development and implementation, enabling the systematic growth of a robust mineral industry. It s necessary to bridge this gap with a comprehensive CMS for South Africa as contemporary developments highlight the need for sustained supplies of these minerals towards energy transition and other enhanced technologies.

1.3 Research problem

Recent developments in the energy transition movement (International Climate Change Agreements, the Paris Agreement, the UN's Sustainable Development Goals, etc) may further drive the decline in the use of, and thus the demand for, coal. However, these changes also present an opportunity to exploit access to the minerals that are crucial for this transition. The South African mining sector has implemented a number of initiatives aimed at reviving or boosting mining activities, such as addressing the backlog for minerals rights applications and setting up the Junior Mining Exploration Fund (JMEF), aimed at supporting private or low-market-cap public companies focused on mineral exploration and development. The newly launched Industrial Development Corporation (IDC) exploration fund and a private-public partnership called the National Energy and Logistics Crisis Committees have also been tasked with addressing operational issues at Transnet, Eskom and other organisations (Government of South Africa, 2024), further contributing to the efforts to improve mining infrastructure and boost the country's economy, which has lagged in the recent past. To all these initiatives, procuring a service provider for the design, implementation and maintenance of a mining licensing system will be key.

Müller (2023), however, argues that there has not been a focused, consolidated effort to take advantage of the current critical mineral supply chain challenges that countries in the global North are experiencing due to geopolitical events including Covid-19 and the Russia-Ukraine conflict. One solution Müller suggests is establishing a CMS which consolidates all the available resources and directs them toward global mining partnerships, which would immensely benefit South Africa and the African region in general (Ge & Liu, 2020).

The lack of a formalised CMS could result in the country missing opportunities to explore and utilise these resources for economic growth and technological advancement in the renewable energy sector, among another uses. It therefore is imperative that South Africa develop a CMS to enable the strategic and cost-effective domestic production of renewable energy components (Benard, 2018).

Therefore, this study assessed CMS and how it may be utilised to enhance South Africa's capability to supply critical minerals locally and globally.

1.4 Research aim and objectives

The aim of this study was to identify mechanisms for the development of an efficient and beneficial CMS that lays the groundwork for proper management and utilisation of critical minerals, benefitting South Africa's socio-economic and environmental endeavours. To this end, the following objectives were formulated:

a. Identify global practices in the formulation of CMS
b. Analyse the relevance and applicability of these practices in the South African context
c. Propose a framework for South Africa's CMS development that can contribute towards the country's 2002 Mineral and Petroleum Resources Development Act (MRPDA) objectives

1.5 Rationale

This paper aimed to contribute to the discussion around enhancing South Africa's role as an active and competitive participant in the global mineral industry. Achieving this will uplift socioeconomic conditions in the country and the region through the deployment of critical minerals in the decarbonisation process, economic development, job opportunities and technological advancement, both at home and globally (International Energy Agency (IEA), 2023).

By developing a comprehensive strategy, South Africa can leverage its vast mineral resources to achieve economic growth, enhance its national security and promote sustainable development (Minerals Council of South Africa (MCSA), 2023).

The findings provide a roadmap for policymakers, industry stakeholders and the academic community, fostering collaboration and ensuring that the benefits of

critical minerals are maximised, while minimising negative environmental and negative social impacts. Additionally, the strategy will advance South Africa and the global communities' goals in the energy transition by supplying critical minerals essential for the manufacture of renewable energy components (Government of South Africa, 2024).

1.6 Delimitations of the study

This is an exploratory study using qualitative methods to uncover insights and understanding in a relatively under-explored area. This research was restricted to publicly available and accessible data, primarily comprising peer-reviewed academic literature, published policies and regulations, and strategies from selected countries with established CMS. Data was retrieved from academic and government websites and databases and may not include unpublished reports or proprietary information. This study assumes that future technological developments will support demand for critical minerals as they are currently defined.

1.7 Abbreviations and definition of terms

CM: Critical mineral. A mineral essential for the economic development and national security of a country whose supply chain may be vulnerable to disruption due to geological scarcity, geopolitical issues or other factors. Examples include lithium, cobalt and rare earth elements (International Energy Agency (IEA), 2023).

CMS: Critical minerals strategy. A framework designed to secure the sustainable and reliable supply of critical minerals (IEA, 2023).

PGMs: Platinum group metals. A set of six metallic elements comprising platinum (Pt), palladium (Pd), rhodium (Rh), ruthenium (Ru), iridium (Ir) and osmium (Os). These metals are valued for their catalytic properties, resistance to wear and

tarnish, and use in industries such as automotive, jewellery and electronics (Minerals Council of South Africa (MCSA), 2023).

DMRE: Department of Mineral Resources and Energy. This South African government department is responsible for administration of the mining and energy sectors. After the May 2024 elections, this ministry was divided into two: the Ministry of Minerals and Petroleum Resources and the Ministry of Electricity and Energy (Government of South Africa, 2024).

ESG: Environmental, social and governance. Criteria for assessing a company's sustainability and ethical impact. ESG standards guide investors and corporate strategies towards sustainable practices (MCSA, 2023).

IDC: Industrial Development Corporation. A South African national development finance institution that supports economic growth and industrial development (Government of South Africa, 2024).

JMEF: Junior Mining Exploration Fund. A fund to which the DMRE and the IDC have jointly contributed R400 million (R200 million each), whose aim is to advance the exploration of critical minerals within the junior mining sector, fostering growth and enhancing South Africa’s mineral exploration capacity (Government of South Africa, 2024).

1.8 Assumptions

This study assumed that nations with a developed CMS are more likely to have a thriving and productive mining industry than those without. The study assumes that South Africa will remain an enabling environment, or even improve in this regard, and that its critical minerals are perceived to be as clean and conflict-free as any other produced in the developed world and can therefore compete fairly.

1.9 Chapter outline

This thesis is structured as follows:

Chapter 1. This chapter provides a contextualisation of the study and discussed the research problem, objectives and justification of the study.

Chapter 2. This chapter reviewed the foundational strategic management literature, emphasising the strategic significance of critical minerals. It discussed the alignment of study objectives with the hypothesis and concluded with a conceptual framework linking the theory to CMSs.

Chapter 3. This section outlined the research methodology and design and detailed the data collection process and its linkage to the hypotheses. It concluded with a description of the thematic analysis process employed.

Chapter 4. Research execution – this chapter presented findings of Critical Mineral Strategies from major mining economies and interpreted the themes from Appendix B to satisfy research objective (a): Identifying global practices in the formulation of Critical Minerals Strategies (CMS). This was achieved through a combination of qualitative document analysis and case study methods to explore international CMS approaches..

Chapter 5. Analysis and discussions – provided a structured analysis and discussion of the findings and explored the relevance and applicability of international CMS practices to South Africa, aligned with objective (b). .

Chapter 6. Recommendation – synthesised the key learnings into a proposed approach for a South African CMS, incorporating strategic, institutional, and operational elements. This chapter proposed a CMS framework to support the objectives of South Africa's 2002 Mineral and Petroleum Resources Development Act (MPRDA), addressing objective (c).

Chapter 7. Conclusion – the final chapter offered the study's conclusions, summarised the key insights, and presented recommendations for policy and future research.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter briefly discusses the fundamental inputs, objectives and preferred outcomes of a general strategy, public sector strategy and CMS from a scholarly perspective (Lenox et al., 2017). It further delves into the specific area of CMSs, highlighting their strategic importance in economic development.

2.1.1 The history of mining in South Africa and global supply contribution

According to Huffman and Woodborne (2021), mining activities in South Africa can be traced back to pre-colonial times – before the arrival of European explorers or colonial agents. Examples such as Mapungubwe, in the northern part of South Africa, underwent substantial mining activities between the years 900 to 1300 CE (United Nations Educational, Scientific and Cultural Organisation [UNESCO] 2002). The 1867 discovery of diamonds near Kimberley, followed by the 1886 Witwatersrand gold rush, catalysed extensive mining activity, leading to the rapid development of mining towns and infrastructure. This era laid the foundation for South Africa's dominance in global mineral markets, particularly in gold, diamonds, platinum group metals (PGMs), coal and manganese (Nauright, 2004).

South Africa's contribution to the global commodities supply is significant. The country was the world's largest producer of gold for many decades; however, its output has declined in recent years owing to the depletion of reserves and rising production costs. Furthermore, South Africa is a significant provider of PGMs, accounting for much of the global supply of platinum (74%), palladium (39%), rhodium (82%), iridium (81%) and ruthenium (90%) (Moller, 2022) – critical components in automotive catalytic converters and various electronics (IEA, 2023). Additionally, South Africa is a major supplier of manganese and chromium, which are pivotal in the global metal and energy sectors (Geological Survey,

2024). Figure 1 illustrates the country's contribution to global commodities, as well as its critical role in the global sphere and its advancement through mineral reserves.

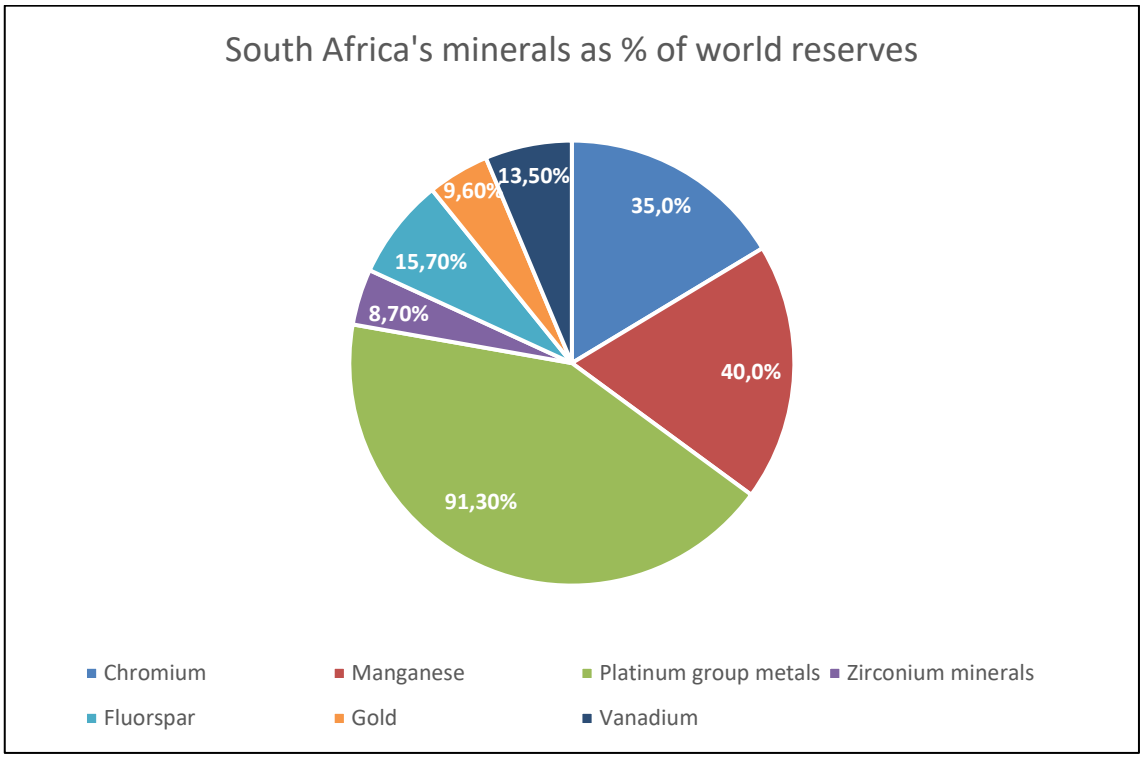

Figure 1. South African contribution to world mineral reserves (MCSA, 2023)

2.1.3 South African mining's economic contribution

The contribution of the mining industry to the South African economy has evolved over the years, reflecting changes in global markets, domestic economic policies and structural shifts within the sector (Benard, 2018). Although mining was once a dominant force, it contributed barely 4.4% of South Africa's gross domestic product (GDP) in 2022, down from 21.3% in 1970, as illustrated in Figure 2 (Minerals Council of South Africa, 2023). Benard further highlights that the mining sector has also been instrumental in driving infrastructure development, from transportation and logistics to energy and water supply, further underscoring its integral role in South Africa's economic landscape. Despite these contributions, its downward trajectory suggests the need to review key strategies to revive its

contribution towards the country's economic prosperity. This demonstrates an urgent need to investigate strategies around the exploitation of emerging minerals – particularly those critical minerals that are essential to rapid global developments and applications such as the energy transition. Figure 2 illustrates the mining industry's declining contribution over time to South Africa's gross domestic product.

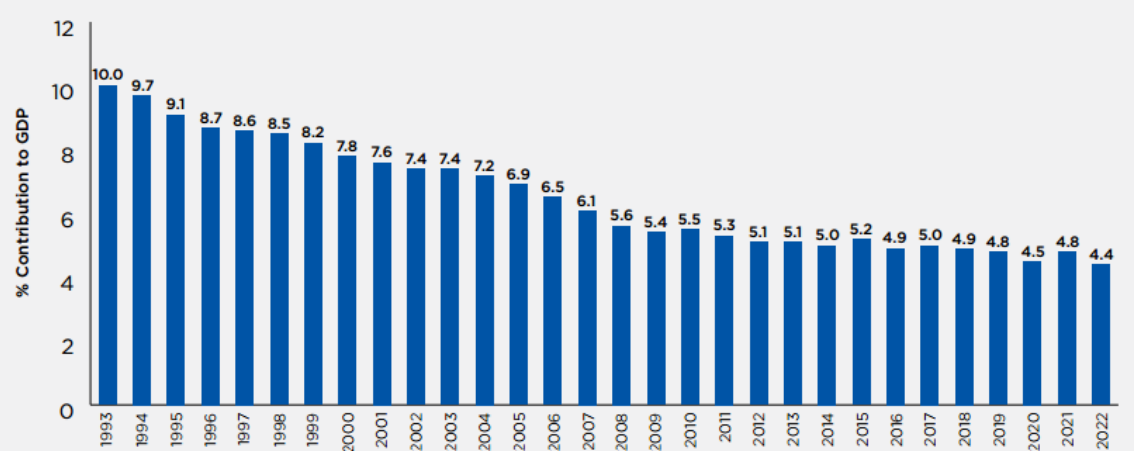

Figure 2. The South African mining industry's percentage contribution to the country's GDP (MCSA, 2023)

2.1.4 Future-facing critical minerals: importance and implications

Critical minerals encompass a broad range of elements, such as lithium, cobalt, nickel, rare earth elements (REEs) and graphite, which are integral to the manufacture of batteries, electric vehicles (EVs), wind turbines and other renewable energy technologies. The burgeoning market demand for these minerals is mostly related to the escalating necessity to mitigate greenhouse gases (GHGs) in accordance with the Paris Agreement, advancements in technologies and rising government funding for low-carbon economies (IEA, 2023). These minerals are found in abundance in South Africa and the Sub-Saharan Africa (SSA) region, prompting the former to prioritise exploring these critical minerals to supply global demands such as energy transition. As outlined in Table 1, South Africa's minerals that are critical to energy transition and thus

targeted for exploration include copper, lithium, nickel, manganese, cobalt, graphite, chromium, molybdenum, zinc, silicon, rare earth elements, coal and uranium (Department of Minerals Resources and Energy, 2022).

Table 1. South Africa's targeted critical minerals (DMRE, 2022)

Minerals	Current/future needs
	Minerals of the future/green economy
Cobalt	
Nickel	
Copper	
Zinc	
Lead	
Rare earth minerals	
	Battery minerals
Vanadium	
Lithium	
	Steelmaking
Manganese	
Iron ore	
	Energy minerals
Coal	
Uranium	
	Hydrogen economy and decarbonisation
PGMs	
Chrome	

2.1.5 South Africa's critical minerals strategy

Several developed countries, such as the United States of America (USA), Canada, Australia and the United Kingdom (UK), have established mineral strategies to align their policies and resources with participating in future-facing mineral industries (India Ministry of Mines, 2023). Barteková and Kemp (2016) argue that that such a strategy provides a framework for prioritising investments, streamlining regulatory processes and fostering innovation, which are critical for securing the sector's sustainable development. By aligning national objectives with global trends, a well-structured strategy enhances the country's capacity to meet economic and technological demands while ensuring long-term resource

security. However, to date no African countries have developed or published a critical strategy document – despite the continent being one of the most mineral-rich across the globe (Africa Natural Resources Management and Investment Centre [ANRC], 2022). This highlights the need for countries such as South Africa to put in place systems and processes to explore their critical minerals to enable their energy transition imperatives and other needs associated with these commodities.

2.2 Strategy, objectives and effective strategy implementation

2.2.1 What is strategy?

Strategy in an organisation encompasses a complex set of actions and resource commitments aimed at achieving superior results (Lawler & Howell-Barber, 2007). According to Fairbanks and Buchko (2018), it involves a pattern of decisions that allocate resources to long-term goals, clearly revealing and determining an organisation's objectives, purposes and goals. Lenox et al. (2017) and Nickols (2008) further emphasise that effective strategy is not just about planning but also about positioning the organisation within its competitive environment to meet these desired outcomes. This provides a foundational understanding of the specific objectives that strategies aim to achieve.

2.2.2 Objectives of strategy

The objectives of an organisation's strategy focus primarily on gaining a sustainable competitive edge and responding adeptly to market opportunities and threats, as noted by Fairbanks and Buchko (2018) and Nezhad et al. (2017). Kaplan and Norton (2004) add that successful strategies involve selecting and excelling in activities that create a sustainable difference in the marketplace, leading to improved performance relative to competitors and the mobilisation of intangible assets for value-creating processes. These objectives underline the

importance of strategic alignment with market demand, setting the stage for exploring how such strategies are formulated and implemented.

2.2.3 General effective strategy implementation

Effective strategy formulation and development require comprehensive planning, clear decision-making and strategic oversight. Integrated models that combine the resource-based view and the industrial organisation perspective, as proposed by Arvand & Baroto, 2016; and Baroto et al., 2014, emphasise the role of balanced scorecards in this process. Borawska (2017) and Neilson et al. (2008) highlight the importance of clarifying decision rights and enhancing information flow within organisations, which are crucial for the successful execution of strategies. This approach not only ensures well-conceived strategic initiatives but also facilitates their effective implementation – essential in the public sector where the stakes include public welfare and service delivery.

2.2.4 Effective strategy implementation in the public sector

In the public sector, strategies' effectiveness is determined through a variety of factors that include robust partnerships and a modern understanding of strategic management (Chiwawa et al., 2020; Elbanna et al., 2016). The use of balanced scorecard systems, as suggested by Setiawan (2012), helps in translating, evaluating and harmonising strategies with organisational goals, thereby improving community service. This systematic evaluation is essential for ensuring that public sector strategies are both effective and adaptable, aligning with the ongoing discussion in the literature about the strategic importance of critical minerals and how CMS should be formulated and subsequently implemented.

2.3 Strategy in critical minerals

The classification and strategic significance of minerals into 'key', 'strategic' and 'critical' categories, underscores their importance in the green economy and

major industries. Galos et al. (2020) and Wu et al. (2020) describe methodologies for identifying these minerals based on consumption and import reliance, highlighting their pivotal roles in modern technology and industry. This discussion leads to broader strategies which countries adopt to secure these vital resources, emphasising the need for robust CMSs.

National strategies for critical minerals, as analysed by Ge and Liu (2020) and Lee et al., (2022), focus on ensuring resource security and supporting national development. The importance of these strategies in maintaining economic stability and reducing supply risk is also noted by The US Presidency (2017), which underscores the necessity of secure and reliable supply while sustainably serving socio-economic needs. The literature threads strategic management across sectors to illustrate a comprehensive view of how strategies are developed, implemented and evaluated to meet both organisational and national goals. Table 2 links the study objectives described above to the hypothesis used to articulate this study.

2.3.1 Relevant strategic management theories for CMS development

In developing a national CMS, it is essential to ground the approach in strategic management theories that support public sector planning, stakeholder integration, and long-term competitive advantage. Several frameworks are particularly relevant.

a). The balanced scorecard framework enables public institutions to align operational activities with broader strategic objectives by translating vision into measurable targets across four perspectives which are financial, customer, internal processes, and learning and growth. For a CMS, this allows performance measurement beyond extraction volumes, including sustainability, beneficiation, and local development (Freitas et al., 2021).

b). Stakeholder theory asserts that organisational success depends on satisfying key stakeholders' needs which are particularly relevant for mineral strategies involving government, communities, industry, and global partners. Effective CMS

design must engage these diverse actors to ensure legitimacy, resilience, and equitable benefit-sharing (Braga et al., 2016).

c). Policy coherence theory is relevant for inter-sectoral strategies like a CMS, policy coherence ensures alignment across departments (e.g., minerals, environment, trade). This framework evaluates the compatibility of objectives and instruments, which is critical in South Africa's fragmented policy environment (Cairney, 2025).

d). Resource-based view focuses on internal capabilities as sources of competitive advantage. Applied to CMS, it argues for leveraging South Africa's unique endowment of critical minerals to build strategic capabilities in processing, innovation, and trade partnerships (Madhani, 2010).

These theories were integrated to frame both the conceptual approach (see revised Figure 3) and the recommendations in Chapter 6, ensuring academic rigour and real-world applicability.

Table 2. Linking objectives and hypotheses

Research objective	Research objective description	Hypothesis
a	Identify global practices in the formulation of CMS.	Global practices can be systematically identified through a comparative analysis of countries with established mineral strategies.
b	Analyse the relevance and applicability of these practices in the South African context.	Certain global practices in CMS are relevant and can be effectively adapted to the South African context.
c	Propose a framework for South Africa's CMS development that can contribute towards the country's 2002 Mineral and Petroleum Resources Development Act (MRPDA) objectives.	Implementing a specifically designed CMS framework based on adapted global practices can contribute to South Africa's mining economy and ESG imperatives.

These hypotheses are structured to provide a clear direction for research and to establish a cause-and-effect relationship between global practices and their applicability to South Africa, as well as the potential impact of a tailored CMS on the country's economic and environmental goals.

2.4 Conclusion

This review highlighted the importance of strategic management in attaining organisational success and national security in diverse industries. An effective strategy formulation requires thorough preparation, execution and evaluation while continually adjusting to the ever-changing global environment. Strategies in the public sector prioritise adaptation, stakeholder engagement and thorough evaluations to improve service delivery. Similarly, the strategic management of crucial minerals emphasises the necessity for nations to ensure the development of key resources necessary for technological progress and economic stability. These learnings collectively demonstrated that innovative and adaptable strategies are necessary to maintain long-term success and resilience in a complex and constantly changing world. Figure 3 illustrated the conceptual framework that this study followed.

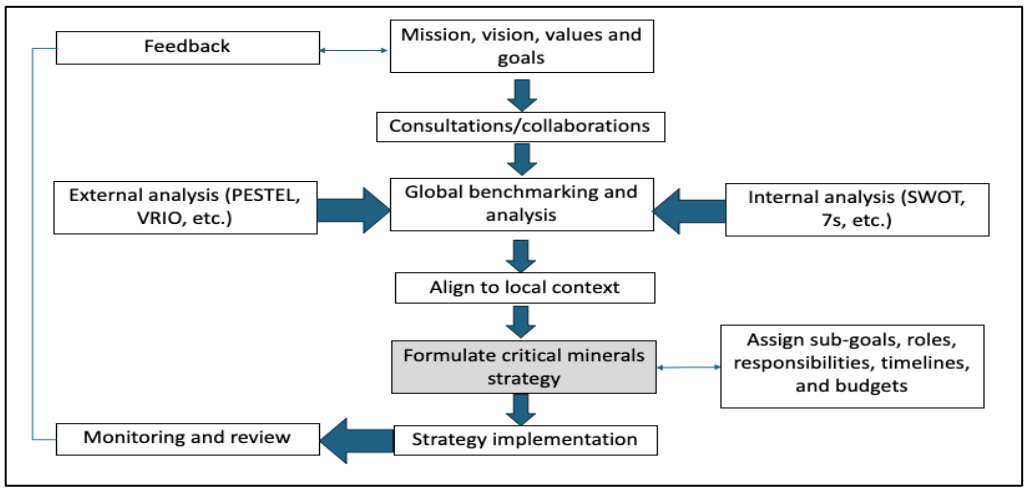

Figure 3. South African CMS conceptual framework (Robbins & Coulter, 2017)

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlined the research methodology used to analyse the key aspects and processes used in formulating global CMSs. A qualitative case study approach using secondary data was applied to this analysis, enabling a thorough examination of intricate phenomena within these nations' contexts and facilitating a nuanced understanding of the initial effects and strategic orientations of each country's CMS.

3.2 Research design

Qualitative case study research is a method used to explore complex phenomena, often in the social and life sciences (Pateliya & Shah, 2013; Sitorus, 2021). It involves in-depth analysis of an individual unit, such as a person, group or event, within its context (Pateliya & Shah, 2013). The qualitative case study method allowed the exploration of different interacting factors within a natural setting (Debout, 2016). Using a case study approach, it delved into examples from the selected countries to reveal insights that could aid the formulation and implementation of a well-rounded CMS for the South African context, ensuring that country-specific nuances are not overlooked. Ratnasari and Sudradjat (2023) highlight that case study research is a versatile methodology used across various disciplines to investigate complex phenomena in real-life contexts. A qualitative multiple-case study design was used to investigate how five major mining economies developed their CMSs. This design was selected for its strength in exploring complex, context-dependent processes (Pateliya & Shah, 2013; Sitorus, 2021). The multiple-case study approach allows for analytical generalisation rather than statistical generalisation, facilitating the comparison of strategic development processes across diverse jurisdictions..

3.3 Case selection

The Northern Miner Group (2024) and the IEA (2023) report that the global 50 most valuable mining companies are located in Canada, China, the USA, Australia, the United Kingdom, South Africa, Russia, India, Mexico and Saudi Arabia. The case studies for this research were chosen exclusively from nations on this list that have developed and published their CMSs (IEA, 2023), specifically Canada, the US, Australia, the UK and India – those economies with the most valuable mining industries that have also published their CMSs.

3.4 Data collection

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This study employed qualitative document analysis as the primary data collection method. Official documents were collected from government portals, international agencies, and industry associations across five selected countries: Australia, Canada, the USA, India, and the UK. The selected documents included critical minerals strategies, policy papers, ministerial statements, and government reports published between 2017 and 2024.

The search strategy involved purposive sampling to ensure the selection of only those documents that explicitly outlined national positions on critical minerals. Search terms used included 'critical minerals strategy', 'green minerals', 'mining policy', and 'mineral supply chain'. A total of 27 documents were identified, downloaded, catalogued, and prepared for thematic analysis. All documents were assessed for authenticity, credibility, and relevance to the research question.

In this case, the population related to the inclusion of documents that were guided by relevance to strategy formulation, critical minerals strategy implementation and potential applicability of insights to the South African context.

3.5 Data analysis

Thematic analysis was employed to code and interpret data across the five case studies. A hybrid approach combining inductive coding (emerging themes) and deductive coding (based on pre-identified themes such as governance, criticality assessment, and implementation frameworks) was applied. Manual coding enabled immersion in the data, facilitating nuanced cross-case comparisons.

Government documents were thoroughly analysed and coded using manual content analysis. The objective was to discern the patterns, themes and classifications that arise from a comparative examination of textual data. This approach follows Ge and Liu (2020), who employed similar analytical instruments for their research study and established their effectiveness. summarises the objectives, hypotheses, research methods and analysis methods proposed for this scholarly research. The data analysis has been fully and successfully conducted in Appendix B.

Table 3. Linking objectives, hypotheses, data collection and analysis method

Research objective	Research objective description	Hypothesis	Data collection	Analysis method
a	Identify global practices in the formulation of CMS.	Global practices can be systematically identified through a comparative analysis of countries with established mineral strategies.	Case study	Thematic
b	Analyse the relevance and applicability of these practices in the South African context.	Certain global practices in CMS are relevant and can be effectively adapted to the South African context.	Case study	Thematic
c	Propose a framework for South Africa's CMS development that can contribute towards the country's 2002 Mineral and Petroleum Resources Development Act (MRPDA) objectives.	Implementing a specifically designed CMS framework based on adapted global practices can contribute to South Africa's mining economy and ESG imperatives.	Case study	Thematic

3.6 Ethical considerations

This study upheld the principles of fairness and scholarly ethics, ensuring that sources are accurately cited and that findings are presented without bias. In addition, the study only used information in the public domain, extracted from online sources or in hard-copy printouts.

3.7 Credibility, and trustworthiness

Quality assurance within the study was maintained through validation techniques including researcher checking with industry experts and peer debriefings.

To ensure rigour in this qualitative study, (Kakar et al., 2023) criteria for trustworthiness were adopted, focusing on credibility, transferability, dependability, and confirmability.

Credibility was strengthened through systematic comparison of CMS features across the five countries and through peer review of emerging codes and themes. Transferability was enhanced by providing detailed context for each national strategy, allowing readers to assess relevance to the South African context. Dependability was ensured by applying a consistent and documented coding procedure (see Appendix B). Confirmability was achieved by maintaining a transparent record of document sources, coding justifications, and analytical memos.

3.8 Limitations

While case study methodology offered rich, contextual insights, its generalisability to other settings, such as South Africa, were interpreted cautiously. Furthermore, reliance on document-based data excludes contemporaneous stakeholder perspectives which could have further enrich findings.

3.9 Summary

This chapter developed a robust methodological framework for studying global CMSs, which served as the basis for conducting a detailed analysis. The findings from this analysis were used to develop a customised approach specifically for South Africa, as represented by the mind map in Figure 4 below.

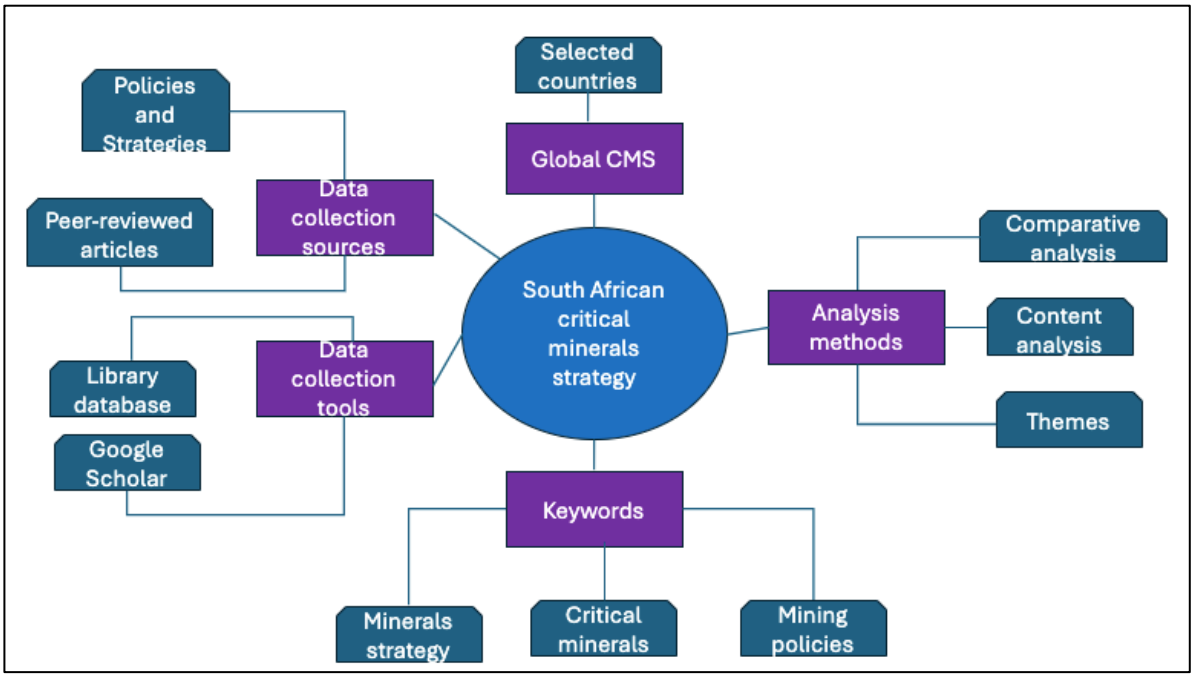

Figure 4. Mind map summary of the research methodology

3.10 Next Steps: Transition to Analysis and Findings

To guide the reader in navigating the research analysis and findings, the structure of the forthcoming chapters is clarified below. This structure followed the progression of the research objectives and thematic analysis process and is shown in the Table 4.

Table 4. Next Chapters, Titles and Roles

Section	Presentation	Corresponding Research Objective	Role
Appendix B	Coding of raw data and identification of themes from case studies	Supports all study objectives	Analysis

Chapter 4	Analysis and results of CMSs from major mining economies – Thematic comparative analysis	Objective (a): Identifying global CMS formulation practices	Findings
Chapter 5	Applying global lessons to the South African context – Relevance testing of themes within local conditions	Objective (b): Analysing relevance and applicability to SA	Contextualising of Findings and Application
Chapter 6	Recommendations toward a South African CMS – Strategic framework proposition	Objective (c): Proposing a framework for South Africa's CMS	Discussion
Chapter 7	Conclusion: Offered the study's summary with key insights and future research recommendations	Objectives (a), (b), and (c)	Summary

CHAPTER 4. RESULTS

4.1. Introduction

This chapter analysed the collected themes and on how the major mining economies of the USA, Australia, the UK, Canada and India have developed their critical minerals strategies in support of the research objective (a).

4.2. Analysising Global practices in CMS formulation

The study's first objective aimed to systematically identify and compare the formulation practices of the major economies' strategies. The study identified four essential contextual inputs, namely national resource endowment and economic context, policy and regulatory environment, stakeholder engagement, and criteria for defining critical minerals, needed to analyse the CMSs of major mining economies. These inputs were selected based on their broad applicability and relevance as outlined in the frameworks of Barteková and Kemp (2016) and Zhang et al. (2023), which emphasise the importance of economic conditions, governance structures and participatory processes in shaping effective resource strategies. By examining these inputs, the study captured the diverse factors that influenced the drafting and execution of CMSs in the selected countries, offering comprehensive insights into their contextual underpinnings. This approach ensured that the analysis not only reflects the unique attributes of each economy but also provides transferable lessons for developing a robust South African CMS, tailored to the country's specific needs and global positioning (Zhang et al., 2023). Figure 5 outlines graphical representation of the CMS publications, excluding updates, in chronological order.

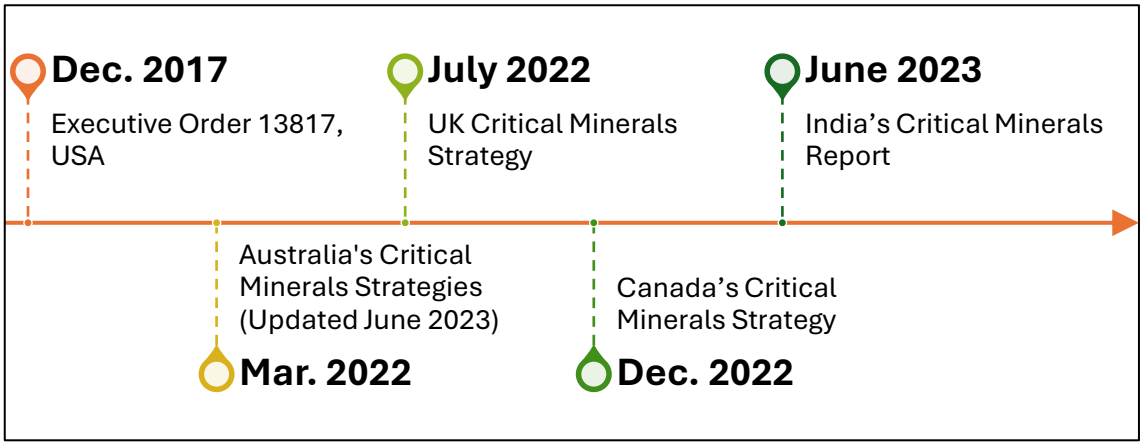

Figure 5. Overview of CMS Chronology, excluding updates (India Ministry of Mines, 2023; Nwaila et al., 2024)

The collected data presented in Table 5, depicting each strategy's development timeline in chronological order (although most were subsequently revised and/or updated) (Hotchkiss et al., 2024). It should be noted that, where publicly available, this study made use of the latest versions of CMSs.

Table 5. Case study CMSs utilised in this research

Country	Title of critical minerals strategy	First published	Updated
United States of America	Executive Order 13817: A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals	December 2017	January 2021
Australia	Critical Minerals Strategy 2023–2030: Australian Government Department of Industry, Science and Resources	July 2022	June 2023
United Kingdom	Resilience for the Future: The United Kingdom's Critical Minerals Strategy	July 2022	March 2023
Canada	Canada's Critical Minerals Strategy: From Exploration to Recycling – Powering the Green and Digital Economy	December 2022	June 2024
India	Critical Minerals for India: Report of the Committee on the Identification of Critical Minerals	June 2023	N/A

4.2.1. The USA's critical minerals strategy

4.2.1.1. National resource endowment and economic context

The USA has a diverse but underdeveloped mineral resource base, necessitating a strategy that focuses on both increasing domestic production and securing international supply chains. Because its economy is already one of the world's largest, the US's CMS concentrates more on maintaining strategic interests, technology leadership and energy security than on economic development. (Department of Energy, 2021). The US government recognises that it may have to form strategic alliances to ensure its supply of those mineral resources it lacks, or of which it has insufficient quantities (Vivoda et al., 2024). This presents an opportunity for resource-rich countries and regions such as South Africa to collaborate with global partners in fostering a robust and sustainable critical minerals industry.

4.2.1.2. Policy and regulatory environment context

The USA's policy environment is shaped by a strong emphasis on national security. The regulatory framework encourages domestic exploration and the production of critical minerals, along with efforts to develop substitutes and enhance recycling. The strategy is implemented through a series of executive orders such as the Inflation Reduction Act, 2022 (IRA), and supported by federal funding aimed at bolstering the country's critical mineral supply chains (Concordel, 2024).With such sound policy and regulatory systems developed and implemented at government level to bolster this framework, the US's CMS is well-supported.

4.2.1.3 Stakeholder engagement

The country's strategy was developed through coordinated efforts among multiple federal agencies, including the Departments of Energy, Defence and Commerce, with the Department of Energy leading the charge. The development process also incorporated input from private sector stakeholders, including the

Minerals Investment Network for Vital Energy Security and Transformation (MINVEST Partnership), reflecting a comprehensive approach to securing critical mineral supply chains (US Department of Energy, 2021). It is observed that stakeholder engagement is a critical element in the development of strategies within the country, including its CMS.

4.2.1.4 Defining critical minerals

The USA has defined critical minerals based on their supply risk and importance to national security and economic prosperity. The strategy prioritises minerals that are essential for defence technologies, renewable energy systems and other critical infrastructures, with a focus on reducing reliance on foreign sources (Concordel, 2024; Vivoda et al., 2024). The US thus acknowledges that a clear definition of ‘critical minerals’ is important, as is a solid understanding of each mineral’s importance to its economic endeavours.

4.2.2. Australia's critical minerals strategy

4.2.2.1 National resource endowment and economic context

Australia is endowed with a vast array of mineral resources and a mature, well-developed mining sector, positioning it as one of the world's leading producers of critical minerals such as lithium, rare earth elements and cobalt. The country's economic reliance on mining, coupled with its strategic focus on green technologies, underscores the importance of securing a stable supply of these minerals (Northey et al., 2023; Sinclair & Coe, 2024). As outlined by the Australian Department of Industry (2023), its strategy leverages these resources to strengthen the country’s position in global supply chains and to support its transition to a low-carbon economy. Australia's approach aims to solidify its position as a leading player in the critical minerals sector.

4.2.2.2 Policy and regulatory environment context

Australia’s policy environment is characterised by strong government support for the mining sector, including incentives for the exploration and development of critical minerals. The regulatory framework emphasises sustainable mining practices, focusing on environmental protection and community engagement. This strategy is supported by significant government funding aimed at enhancing Australia’s critical mineral processing capabilities and securing international partnerships (Northey et al., 2023; Sinclair & Coe, 2024). Australia’s case thus demonstrates the need for government support in establishing and implementing a robust CMS.

4.2.2.3 Stakeholder engagement

The development of Australia's CMS, headed up by the Department of Industry, Science, Energy and Resources, involved extensive engagement with a wide range of stakeholders, including government agencies, industry bodies and First Nations communities. The inclusion of Indigenous Australians in these talks was a significant aspect of this engagement, designed to ensure that the benefits of mining activities were equitably shared (Australian Department of Industry, 2023). The task force responsible for the strategy actively sought input from all these groups to ensure that the strategy reflected their needs and priorities, building on the Critical Minerals Report developed by Geoscience Australia.

4.2.2.4 Defining critical minerals

Australia defines critical minerals as those essential for economic well-being but whose supply may be at risk due to factors such as geological scarcity, geopolitical considerations or market dynamics. The strategy emphasises maintaining a diversified supply base and enhancing domestic processing capabilities to mitigate supply risks. The list of critical minerals is regularly reviewed and updated to reflect global market changes and Australia’s evolving economic priorities (Australian Department of Industry, 2023; Sinclair & Coe,

2024). It is clear from Australia's case that regular definition and review of critical minerals is an important aspect of a country's CMS planning.

4.2.3. United Kingdom critical minerals strategy

4.2.3.1 National resource endowment and economic context

Unlike the USA and Australia, the UK has limited domestic mineral resources, making it heavily reliant on imports of critical minerals. The country's strategy acknowledges this dependency and seeks to strengthen the UK's position through international partnerships and investments in innovation. The economic context is driven by the need to secure critical inputs for key industries such as aerospace, automotive and renewable energy (UK Department for Business, 2023).

4.2.3.2 Policy and regulatory environment context

The UK's policy and regulatory environment focused on promoting sustainable and responsible sourcing of critical minerals. This strategy is supported by government initiatives aimed at enhancing the UK's status as a leader in ESG standards and fostering global cooperation in critical mineral supply chains. Regulatory frameworks are in place to ensure that all imports meet high environmental and social standards (Josso et al., 2023; UK Secretary of State for Business, 2022).

4.2.3.3 Stakeholder engagement

The UK government, through its Department for Business, Energy and Industrial Strategy, engaged with various stakeholders including industry representatives, financial institutions and international partners in developing its critical mineral strategy. This led to the development of the Task and Finish Group on Industry Resilience for Critical Minerals' report to support the UK's CMS (Josso et al., 2023). According to the UK's then-Secretary of State for Business (2022), the

strategy prioritises traceable supply chains and high ESG standards, reflecting the UK's commitment to responsible sourcing. This further necessitates the need for the involvement of various stakeholders in the development of the UK's CMS.

4.2.3.4 Defining critical minerals

The UK defines critical minerals based on their economic importance and the risk of supply disruption. The strategy focused on minerals essential for the UK's industrial sectors and aims to mitigate supply risks by diversifying sources and enhancing domestic capabilities (Josso et al., 2023). This approach is particularly prudent for a nation with limited domestic reserves of critical raw minerals.

4.2.4. Canada's critical minerals strategy

4.2.4.1 National resource endowment and economic context

Canada is rich in mineral resources, including significant deposits of nickel, cobalt and rare earth elements. The mining sector is a vital component of Canada's economy and contributes significantly to its GDP and employment. The country's focus on transitioning to a low-carbon economy further elevates the importance of securing a stable supply of critical minerals (Canada Minister of Energy and Natural Resources, 2024)

4.2.4.2 Policy and regulatory environment context

Like the UK's, Canada's policy framework emphasises sustainable development and ESG standards. The regulatory environment is designed to promote responsible mining practices while fostering innovation in critical mineral processing and recycling. The strategy is bolstered by government initiatives such as the Environmental Protection and Reconciliation Initiative and the Critical Minerals Infrastructure Fund, which aim to increase Indigenous participation in the sector and secure Canada's position in global critical mineral supply chains (Canada Minister of Mineral Resources, 2022; Kerr, 2023)

4.2.4.3 Stakeholder engagement

Similar to the other countries discussed, Canada's CMS development was marked by a comprehensive stakeholder engagement, further cementing this element's importance in the CMS development process. Through its Natural Resources Canada department, the government also conducted extensive consultations with Indigenous communities, industry stakeholders and provincial and territorial governments. This inclusive approach was part of Canada's broader commitment to reconciliation, ensuring that Indigenous peoples are active partners in the critical minerals sector (Saint, 2023).

4.2.4.4 Defining critical minerals

Canada's definition of critical minerals is informed by considerations of economic security, environmental sustainability and its role in the global transition to a low-carbon economy. The strategy includes a dynamic list of critical minerals which is regularly updated to reflect shifts in global demand and technological advancements (Kerr, 2023).

4.2.5. India's critical minerals strategy

4.2.5.1 National resource endowment and economic context

India has significant mineral resources, but many critical minerals such as lithium and cobalt are not found in sufficient quantities to fulfil domestic needs. The economic context of India's strategy is shaped by its ambition to become a global manufacturing hub, which necessitates a stable supply of critical minerals for sectors such as electronics, defence and renewable energy (India Ministry of Mines, 2023). As with the other countries in question, India's economic ambitions demonstrate the need to align the supply of minerals with strategies such as CMS.

4.2.5.2 Policy and regulatory environment

India's policy environment is geared toward enhancing domestic exploration and processing of critical minerals. The strategy is supported by government initiatives such as the Mines and Minerals Development and Regulation Amendment Act of 2023 (MMDR), aimed at attracting investment in mining and processing infrastructure as well as fostering international partnerships. Regulatory frameworks are being developed to ensure that sustainable and responsible mining practices are in line with global standards (Jain, 2024).

4.2.5.3 Stakeholder engagement

India's strategy, spearheaded by the Ministry of Mines, was developed through extensive inter-ministerial consultations and engagements with international organisations and industry stakeholders. This collaborative approach ensured that the strategy addressed critical mineral needs across various sectors of the economy (Indian Ministry of Mines, 2023).

4.2.5.4 Defining critical minerals

India defines critical minerals as those essential for economic development and national security, particularly those at risk of supply disruption due to geopolitical factors or concentrated supply sources. The strategy emphasises the importance of diversifying supply chains and increasing domestic production to reduce dependency on imports (Indian Ministry of Mines, 2023).

4.3 Key themes and contrasts

This sub-section identified the key themes that emerge from an examination of the various mining economies' critical mineral strategies, as shown in Table 5, using the thematic analysis method (covered in Appendix B). These key themes assist the author in guiding the formulation of the South African CMS. The author also conducts a comparative analysis of the critical minerals strategies, outlined

in Table 5, which, when used together with the context provided above, streamlines the issues relating to the formulation of CMSs.

Table 6. Common key themes across major economies' critical minerals strategies

Theme/component	Description
National security and economic resilience	All the strategies discussed emphasised the need to secure access to critical minerals as vital to national security, economic stability and technological advancement. This is especially important in reducing reliance on imports, particularly from China (Australia Department of Industry, 2023; US Department of Energy, 2021).
Sustainability and ESG standards	There was a shared focus on promoting sustainable mining and processing practices, with an emphasis on meeting high ESG standards (Canada Minister of Energy and Natural Resources, 2024; UK Department for Business, 2023).
Indigenous and local partnerships	Countries like Canada and Australia have highlighted the importance of including Indigenous communities in decision-making and ensuring equitable benefits from critical mineral projects (Australia Department of Industry, 2023; Canada Minister of Energy and Natural Resources, 2024).
Diversification of supply chains	All countries aimed to reduce reliance on a few dominant suppliers (e.g., China) by diversifying supply chains through domestic development and

	international partnerships (Indian Ministry of Mines, 2023; US Department of Energy, 2021).
Innovation and technology	There was significant investment in research and development for recycling technologies, substitution of critical minerals and alternative materials to mitigate supply risks (UK Department for Business, 2023; US Department of Energy, 2021).

Table 6 showed the major mining economies' critical mineral strategies focus areas and their immediate outcomes. These CMSs have been formulated recently, in the last five to eight years, as seen in the CMS chronology table. The immediate outcomes provided a benchmark for what is possible when a mining economy has a formulated CMS.

Table 7. Differences in approaches and immediate outcomes

Country	Approach	Immediate outcomes
United States	The US's strategy is heavily focused on national security and reducing reliance on Chinese supply chains. It emphasises domestic production and the development of advanced recycling technologies (US Department of Energy, 2018).	The US has committed substantial funding to bolster domestic critical mineral production and recycling. For instance, the Department of Energy announced over USD3 billion across 25 projects through the Bipartisan Infrastructure Law to extract, process and recycle critical minerals and materials, as well as to support next-generation

		battery manufacturing (The White House, 2024).
Canada	Canada's strategy centres on economic reconciliation with Indigenous peoples and sustainable development. It emphasises collaboration with provincial governments and the private sector to expand exploration and processing capabilities (Canada Minister of Mineral Resources, 2022).	Canada has committed up to CAD3.8 billion over eight years, beginning in 2022–23, as part of its inaugural critical minerals strategy. This funding supports activities such as geoscience exploration, mineral processing, manufacturing, recycling and research and development (Minister of Natural Resources, 2022).
Australia	Australia focuses on leveraging its geological endowment to become a global leader in critical minerals – especially in lithium, rare earth elements and cobalt. Its strategy promotes exploration of underexplored regions and investment in domestic processing capabilities (Australian Department of Industry, 2023).	Australia has committed AUD2 billion to developing its critical minerals industry. It aims to reduce reliance on Chinese imports and is expanding its processing capabilities. Partnerships with the US and Japan have been established to diversify supply chains (The Hon Madeleine King MP, 2023).
United Kingdom	The UK emphasises resilient and traceable supply chains, with a strong focus on sustainability and ESG	The United Kingdom has allocated GBP15 million to the Circular Critical Materials Supply Chains programme, aimed at

	standards. The strategy encourages the development of alternative materials and recycling technologies (UK Secretary of State for Business, 2022).	enhancing the recycling of rare earth elements and strengthening critical mineral supply chains. The UK has established international partnerships to secure critical mineral supplies to bolster supply chains for materials like copper, lithium and nickel (Department for Business and Trade, 2023).
India	India's approach is driven by its need to fuel its growing manufacturing sector and reduce import dependency. Its strategy includes forming international partnerships and enhancing domestic exploration and processing capabilities (India Ministry of Mines, 2023).	The Geological Survey of India (GSI) has increased its exploration projects for critical and strategic minerals from 118 in 2021–22 to 196 in 2024–25, reflecting a concerted effort to bolster domestic supply chains (Ministry of Mines, 2024) and signed several MoUs with countries like Australia and Argentina to secure minerals such as lithium and cobalt (The Economic Times, 2023).

4.4 Conclusion

While common goals exist across these CMSs, such as securing supply chains, promoting sustainable practices and fostering innovation, each country tailors its approach to its specific national needs. Collectively, these national strategies demonstrated a global acknowledgement of the critical role that minerals play in

national security and economic prosperity. Each country's tailored approach addressed specific national priorities and leveraged its unique geographic, economic and technological advantages.

CHAPTER 5. DISCUSSIONS

5.1 Introduction

This chapter contextualises the findings from Chapter 4 and applies the lessons to a South African context.. This chapter therefore covered t research objective (b) , which is to analyse the relevance and applicability of these practices in the South African context.

5.2 South Africa's national resource endowment and economic context

South Africa's extensive mineral wealth and well-established mining and export capabilities have historically cemented its status as one of the leading global mining powers, contributing significantly to its economy for over 150 years. In 2022, the contribution of the mining sector to the national GDP increased by 4%, reaching nearly ZAR494 billion, maintaining a consistent share of approximately 7.5% compared to 2021. The sector also saw a net increase of 15,500 jobs, raising total employment in the mining industry to over 475,000 (DMRE, 2023; MCSA, 2023).

South Africa relies heavily on coal-fired power plants to supply approximately 80% of the nation's electricity, highlighting the commodity's critical role in the country's energy-intensive economy (DMRE, 2023). In 2022, mineral production reached a record high of ZAR1.18 trillion, driven by elevated global commodity prices and influenced notably by geopolitical tensions such as the conflict in Eastern Europe (International Energy Agency, 2024). However, the need for energy transition both globally and locally requires a new approach to mineral exploration activities. This context underscored how critically important it is that South Africa seize the opportunity presented by the emergent demand for critical minerals to drive much-needed national improvements such as energy transition (among others).

5.3 Policy and regulatory environment

South Africa has developed a regulatory framework to guide its mineral exploration and mining activities in a sustainable and socio-economically beneficial manner. Specifically, some of the key applicable policies that influence the critical minerals landscape in South Africa are outlined in Table 7. These demonstrated the country's progress so far regarding the regulatory framework and its intended purpose of ensuring suitability for enhancing the country's socio-economic endeavours.

Table 8. Key policies and legislation influencing South Africa's critical minerals landscape

Category	Policy/legislation	Description
National policies	**National Development Plan (NDP)**	Sets long-term development objectives for economic growth.
	Integrated Energy Plan (IEP) and **Integrated Resource Plans (IRP)**	Outlines energy strategies for sustainability and security.
	Industrial Policy Action Plan (IPAP)	Emphasises industrialisation through value addition and the development of strategic sectors.
	Electricity Pricing Policy (EPP)	Ensures equitable electricity pricing.
	Paris Agreement (2016)	Commits South Africa to climate action and carbon reduction strategies.
Primary legislative frameworks	**Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)**	Governs mineral rights and promotes sustainable development.

	Mine Health and Safety Act, 1996 (Act No. 29 of 1996)	Ensures the health and safety of workers in the mining industry.
	Mining Titles Registration Act, **Diamonds Act**, **Precious Metals Act**, **Geoscience Act**, **Mineral Technology Act**	Regulates various aspects of mining and geological activities.
Energy sector legislation	**National Energy Act, 2008 (Act No. 34 of 2008)**	Provides a framework for energy governance.
	Electricity Regulation Act, 2006 (Act No. 4 of 2006)	Governs the regulation of electricity generation and distribution.
	Petroleum Products Act, 1977 (Act No. 120 of 1977)	Regulates petroleum product use and distribution.
	Central Energy Fund Act, 1977 (Act No. 38 of 1977)	Establishes the management of energy resources and funding mechanisms.
	Nuclear Energy Act, 1999 (Act No. 46 of 1999)	Regulates nuclear energy and safety.
Environmental legislation	**National Environmental Management Act, 1999 (Act No. 107 of 1999)**	Integrates environmental sustainability into mining and energy practices.

5.3.1 Policy coherence in South Africa

Policy coherence, defined as the alignment of objectives, processes and actions across government departments and agencies, is critical for effective governance and sustainable development (Shawoo et al., 2023). However, according to Emmanuel (2024), South Africa faces persistent challenges in achieving such coherence, particularly within key sectors such as mining and energy. Misaligned objectives, fragmented institutional frameworks and overlapping mandates create regulatory uncertainties and inefficiencies which hinder economic growth and

policy implementation (Cloete, 2018). For instance, the lack of coordination between environmental and mining regulations has delayed critical projects, demonstrating the need for a more integrated approach (Cloete, 2018; Emmanuel, 2024).

5.3.2 Recommendations for policy alignment

To align current policies with the proposed CMS, South Africa should prioritise enhancing policy coherence by developing a cross-sectoral framework that integrates mining, environmental and industrial objectives (Montmasson-Clair & Patel, 2024). Establishing formal mechanisms for stakeholder consultation will ensure inclusive decision-making and foster trust among communities and industry players (Mbanda & Fourie, 2020). Institutional coordination must also be improved by streamlining interdepartmental processes and clarifying mandates to reduce inefficiencies (Zembe et al., 2022).

Emmanuel (2024) and Montmasson-Clair and Patel (2024) conclude that supportive policies and regulatory frameworks are essential for the successful implementation of a critical minerals strategy. In the context of South Africa, this framework should be designed to promote sustainable mining practices, foster innovation and secure international partnerships. The intersection of policies in the minerals and energy sectors plays a significant role in shaping such a strategy.

5.4 Stakeholder engagement

To align with practices of stakeholder engagement and inclusive approach, this subsection assessed the country's key stakeholders likely to influence the CMS and their roles in relation to the mining sector.

5.4.1 Government agencies

The Ministry of Mineral and Petroleum Resources (DMRE), which oversees agencies such as the Geoscience Council of South Africa, collaborates in administrating the mining industry with several key stakeholders, including the Department of Electricity and Energy (DEE); the Department of Trade, Industry and Competition (DTIC); the Department of Agriculture (DoA); the Department of Forestry, Fisheries and the Environment (DFFE); the Department of Science, Technology and Innovation (DSTI), which manages the Council for Scientific and Industrial Research (CSIR); and the National Treasury through the Department of Finance (DoF) (DMRE, 2023). To ensure it is aligned with its mandate, the DMRE outlined the following five priorities to be undertaken in their 2023/24 fiscal year:

1. Implementation of the Mining Licensing System
2. Addressing the backlog in licensing
3. Launching exploration support funds
4. Developing South Africa's CMS
5. Supporting artisanal and small-scale mining (DMRE, 2023)

The first three items have seen some progress, along with efforts to boost critical mineral exploration and foster new mining opportunities. The fourth item, however, is most relevant to this study – and, according to the Government of South Africa (2024) and Minerals Council South Africa (2024), it has not yet been fulfilled by the DMRE.

South Africa’s exploration activities have declined significantly from 5% of global exploration expenditure in 2003 to below 1%, which could herald future production constraints (Minerals Council of South Africa, 2023). To counter this trend the DMRE, with support from the Industrial Development Corporation (IDC), launched a ZAR400 million exploration support fund for emerging miners (the Junior Mining Exploration Fund (JMEF)) that is targeted at critical minerals including copper, nickel, graphite, lithium and rare earth elements (McKay, 2024).

According to Stoddard (2024), the DMRE has addressed 40% of the licensing backlog that was caused by inefficiency in the SAMRAD system for processing mining and prospecting applications, so further work is needed to fully resolve the system's efficiency. DMRE signed a service level agreement (SLA) with PGM Consortium to modernise South Africa's mineral licensing system (Project Indwe, which implements a cadastral system used to manage land parcels and property rights), enhance transparency, streamline regulatory processes and support sustainable mining growth (McKay, 2024).

Challenges such as rail and port logistics, coupled with electricity shortages, remain significant constraints for the mining sector. The opportunity cost from logistical issues rose to ZAR50 billion in 2022 from ZAR35 billion in 2021, affecting the sector's ability to leverage high global commodity prices (Minerals Council of South Africa, 2023). The global race for critical minerals essential for a low-carbon future is intensifying, driven by substantial governmental investments to secure these resources for industries (IEA, 2023). South Africa’s rich mineral endowment must be leveraged not only for revenue but to support economic growth and sustainability (Montmasson-Clair & Patel, 2024).

5.4.2 The Minerals Council of South Africa

The Minerals Council of South Africa functions as an industry association representing mining employers and advocates for the interests of the South African mining sector. It provides strategic support and advisory services and promotes its members’ collective interests. One of its primary roles is to facilitate

interactions among mining employers to discuss policy and shared concerns, formulating unified industry positions. The council's initiatives are designed to foster voluntary collaboration among members while respecting their autonomy (MCSA, 2024). The council also serves as an advocate for the mining industry, liaising with government entities to communicate policies and positions endorsed by its members. Notably, the Minerals Council has played an active role in contributing to the development of the South African CMS. It has participated as part of a committee dedicated to crafting this strategy, providing strategic input and facilitating the alignment of industry perspectives with national and global priorities (Creamer Media, 2023; MCSA, 2024).

5.4.3 Investors (including commercial banks, development banks and private equity)

Engagement with South African financial institutions such as Nedbank Investment Bank, Standard Bank Corporate and Investment Banking (CIB), and ABSA is essential for gathering insights into investors' expectations of the CMS. Additionally, consultations with key development finance institutions including the Industrial Development Corporation (IDC), Development Bank of Southern Africa (DBSA) and the Public Investment Corporation (PIC) provide valuable perspectives on strategic investment requirements and financing expectations (Goga et al., 2019; gov.za, 2023). Furthermore, the inclusion of private equity firms in these discussions ensures a comprehensive understanding of private sector investment criteria and interests regarding the CMS (Goga et al., 2019; Govreau, 2024).

5.4.4 Communities, advocacy groups and thinktanks

Engagement with local communities is essential to ensuring alignment with the requirements of the mining industry and fostering inclusion, thereby preventing the conflicts that can arise from inadequate consultation and communication. The case of Xolobeni on the Wild Coast exemplifies the consequences of neglecting

such engagement: potential titanium mining was halted by community opposition due to insufficient consultation, resulting in a prolonged conflict marked by violence (Healy, 2022). This highlights the importance of effective and transparent communication to build trust and gain social license for mining projects (Healy, 2022; Montmasson-Clair et al., 2024).

Several notable advocacy groups, thinktanks and similar entities – including the Mapungubwe Institute for Strategic Reflection (MISTRA), the African Centre for a Green Economy (AfriCGE), the Economic Policy Research Institute (EPRI) and Business Unity South Africa (BUSA) – are well positioned to contribute unique perspectives and specialised expertise to mining-related initiatives (MISTRA, 2020; Jahre, 2021; Woermann & Engelbrecht, 2019; You et al., 2019).

5.4.5 Regional alliances

The development of a strategy that includes partnerships with regional bodies such as the African Continental Free Trade Area (AfCFTA) and the Southern African Development Community (SADC), as well as collaborations with individual Sub-Saharan economies such as Zambia, Botswana, Tanzania, Zimbabwe and the Democratic Republic of the Congo (DRC), presents significant opportunities for procuring and beneficiating critical minerals in South Africa. The success of such collaborations, however, is contingent on the enhancement of infrastructure connectivity between South Africa and neighbouring regions to facilitate efficient transport and trade (ANRC, 2022; Debrah et al., 2024).

The establishment of a regional mining district would strengthen Africa's position in the global minerals market and foster collective economic growth. This regional integration would not only bolster trade but also support value addition and industrialisation across member states (Montmasson-Clair et al., 2024).

5.5 Defining critical minerals for South Africa

A clear and adaptive framework for defining critical minerals is essential. South Africa has already developed a critical minerals exploration target list, as shown in Chapter 2 (Table 1), which should be augmented to create a list of critical minerals that reflects its economic and security needs, with regular updates to account for global supply and demand dynamics changes.

5.5.1 Criticality assessment approach

Criticality assessment in a critical minerals strategy involved evaluating the importance and supply risk of minerals that are essential for various industries, especially for clean energy technologies (Hayes & McCullough, 2018; Hotchkiss et al., 2024). The key themes identified in Chapter 4 was used to assess how critical a mineral is to the economy and therefore to its critical minerals strategy. While this is important for this research topic, it did not fall under the objectives of this study, and for that reason is discussed in more detail in Appendix C.

5.5.2 Suggested initial critical list

The list aligned with the framework proposed by Zhang et al. (2023), which recommends that South Africa classify critical minerals (CMs) into two categories:

- export-focused CMs – minerals critical to global markets
- domestic-priority CMs – materials essential for national development and energy transition

Table 9. Major economies' CM classification lists with a suggested South African list (ANRC, 2022; DMRE, 2022; India Ministry of Mines, 2023)

No.	Mineral	Japan	US	South Korea	Australia	UK	Canada	India	South Africa
	CMS published	2018	2021	2020	2023	2023	2024	2023	E2025
1	Antimony	✓	✓	✓	✓	✓	✓	✓	✓
2	Beryllium	✓	✓	✓	✓	x	x	✓	✓
3	Bismuth		✓	✓	✓	✓	✓	✓	✓
4	Cobalt	✓	✓	✓	✓	✓	✓	✓	✓
5	Gallium	✓	✓	✓	✓	✓	✓	✓	✓
6	Germanium	✓	✓	✓	✓	x	✓	✓	✓
7	Graphite	X	✓	x	✓	✓	✓	✓	✓
8	Indium	✓	✓	✓	✓	✓	✓	✓	✓
9	Lithium	✓	✓	✓	✓	✓	✓	✓	✓
10	Molybdenum	✓	x	✓	x	x	✓	✓	✓
11	Niobium	✓	✓	✓	✓	✓	✓	✓	✓
12	Nickel	✓	✓	✓	x	x	✓	✓	✓
13	PGMs	✓	✓	✓	✓	✓	✓	✓	✓
14	REE	✓	x	✓	✓	✓	✓	✓	✓
15	Silicon	X	x	✓	✓	✓		✓	✓
16	Tantalum	✓	x	✓	✓	✓	✓	✓	✓
17	Tellurium	X	✓	✓	x	✓	✓	✓	✓
18	Tin	✓	✓	✓	x	✓	✓	✓	✓
19	Titanium	✓	✓	✓	✓	x	✓	✓	✓
20	Tungsten	✓	✓	✓	✓	✓	✓	✓	✓
21	Vanadium	✓	✓	✓	✓	✓	✓	✓	✓

22	Chromium	✓	✓	✓	✓		✓	x	✓
23	Magnesium	✓	✓	✓	✓	✓	✓	x	✓
24	Manganese	✓	✓	✓	✓	✓	✓	x	✓
25	Barite	X	✓	✓	x	x	x	x	x
26	Caesium	X	✓	✓	x	x	✓	x	✓
27	Copper	✓	x	x	x	x	✓	✓	✓
28	Hafnium	X	✓	✓	✓	x	x	✓	✓
29	Lead	✓	x	x	x	x	x	x	✓
30	Rhenium	✓	x	✓	✓	x	x	✓	✓
31	Scandium	X	✓	x	✓	x	✓	x	x
32	Strontium	✓	x	✓	x	x	x	✓	✓
33	Zinc	X	✓	x	x	x	✓	x	✓
34	Zirconium	✓	x	✓	✓	x	x	✓	✓
35	Phosphorous	✓	x	✓	x	x	x	✓	x
36	Potash	X	x	x	x	x	✓	✓	✓
37	High purity alumina	X	x	x	✓	x	x	x	x
38	Aluminium	X	✓	x	x	x	✓	x	✓
39	Arsenic	X	✓	✓	x	x	x	x	X
40	Bauxite	X	x	x	x	x	x	x	x
41	Boron	X	x	✓	x	x	x	x	X
42	Cadmium	X	x	✓	x	x	x	✓	x
43	Cerium	X	✓	x	x	x	x	✓	x
44	Diamond	✓	x	x	x	x	x	x	x
45	Dysprosium	X	✓	x	x	x	x	✓	x
46	Erbium	X	✓	x	x	x	x	✓	x
47	Europium	X	✓	x	x	x	x	✓	x

48	Fluorite	✓	x	x	x	x	x	x	x
49	Fluorspar	X	✓	x	x	x	✓	x	✓
50	Gadolinium	x	✓	x	x	x	x	x	x
51	Gold	✓	x	x	x	x	x	x	x
52	Gypsum	x	x	x	x	x	x	x	x
53	Helium	x	x	x	✓	x	✓	x	✓
54	Holmium	x	✓	x	x	x	x	✓	x
55	Iron ore	x	x	x	x	x	x	✓	✓
56	Limestone	x	x	x	x	x	x	x	x
57	Lanthanum	x	✓	x	x	x	x	x	x
58	Lutetium	x	✓	x	x	x	x	✓	x
59	Neodymium	x	✓	x	x	x	x	✓	x
60	Praseodymium	x	✓	x	x	x	x	✓	x
61	Rubidium	x	✓	x	x	x	x	x	x
62	Samarium	x	✓	x	x	x	x	✓	x
63	Silver	✓	x	x	x	x	x	x	x
64	Selenium	x	x	✓	x	x	x	✓	x
65	Terbium	x	✓	x	x	x	x	x	x
66	Thulium	x	✓	✓	x	x	x	x	x
67	Uranium	x	x	x	x	x	✓	x	✓
68	Ytterbium	x	✓	x	x	x	x	✓	x
69	Yttrium	x	✓	x	x	x	x	✓	x
70	Coal	x	x	x	x	x	x	x	✓

***Note**: The minerals highlighted in green* XXXXXX *are subsets of those highlighted in brown* 14 REE *, representing rare earth minerals, which*

are listed separately for clarity. The light blue  *highlights indicate minerals included in the exploration strategy critical minerals list discussed in Chapter 2.*

This initial list identified 38 minerals as critical, with 14 already featured in the 2022 exploration strategy document. The accuracy of this initial critical minerals list can be supported by applying criticality assessment formulas developed by major global economies.

This process was interactive, involving periodic feedback from collaborators, as outlined in Chapter 4. The list should be reviewed and updated every three to five years to align with national priorities and evolving economic and industrial needs (Zhang et al., 2023).

CHAPTER 6. RECOMMENDATIONS

6.1 Introduction

This section provides recommendations towards the development of South Africa's critical minerals strategy. Given South Africa's developing economic position and its vast mineral endowment, including numerous critical minerals, the country's strategy should be designed to maximise its competitive advantages while addressing structural challenges. This final chapter covered research objective (c) by proposing a framework to implement the proposed practices discussed in the previous chapter, thereby concluding the study with the recommended framework. The following recommendations outlined the approach focus areas, key themes and suggested outcomes for a South African critical minerals strategy.

6.2 Recommended key themes for South Africa's CMS

6.2.1 National security

As Australia did with its *Exploring for the Future* initiative, South Africa should invest in pre-competitive geoscience data to attract international and local investment (Australian Department of Industry, 2023). The IDC's JMEF and the implementation of the cadastral licensing system discussed in the previous chapter will help to kick-start this process and play a pivotal role in mapping critical mineral resources and enhancing exploration efforts in underexplored regions of South Africa.

There is a need for South Africa to expand its domestic processing capacity to retain more value within the country. Countries like Australia have shown that by building local processing industries, nations can reduce their dependence on raw material exports and increase economic value. South Africa is home to several lithium battery manufacturers and suppliers, contributing to the country's energy

storage and renewable energy sectors (Montmasson-Clair et al., 2021). By establishing downstream processing industries (e.g., battery manufacturing), South Africa can link its rich mineral resources to domestic job creation, as was the outcome of Canada's focus on green technology and the EV supply chain (Canada Minister of Energy and Natural Resources, 2024). South Africa could thus develop industries around critical minerals to stimulate industrialisation and employment.

These exploration and processing initiatives align with the dual priorities of addressing economic importance and mitigating supply risks, as highlighted by global economies and detailed in Chapter 4's key themes. These initiatives reflect a strategic effort to secure critical mineral value chains while supporting economic resilience and reducing reliance on external sources.

6.2.2 Diversification of supply chains

South Africa should form strategic partnerships with major global economies such as the USA, European Union and Asian countries, following the example of countries like Canada and Australia, which have diversified their critical mineral supply chains by forging key international partnerships (Australia Department of Industry, 2024). The country should pursue similar agreements to secure technology transfer, investment and markets for its critical minerals. The US has an advanced policy environment, wherein the IRA provides incentives (funding, tax breaks, etc) to encourage local mining and processing of critical minerals. Should South Africa introduce similar policies to support its critical minerals industry and pursue strategic partnerships to supply critical minerals to the USA, this could yield significant benefits, particularly if the agreement includes a technology knowledge exchange component.

Leveraging African partnerships to create a regional hub for critical minerals should be pursued. Regional collaboration with other African nations would enhance the region's infrastructure, logistics and collective bargaining power in the global market, similar to Canada's strategy of working closely with the US to

secure shared resources and infrastructure (Canada Minister of Energy and Natural Resources, 2024).

Mitigating supply risk, focusing on strategies to enhance resource security and reduce vulnerabilities in critical mineral supply chains,is emphasised by global mining economies and outlined in Chapter 4's key themes; both the US's and Australia's strategies emphasise the importance of supply chain diversification (Montmasson-Clair et al., 2024). Engaging with multiple international markets to diversify critical mineral supply chains will reduce South Africa's reliance on a single country (such as China) and ensure the stability of supply chains.

6.2.3 Sustainability and ESG standards (including Indigenous and local partnerships)

Fostering sustainable practices and inclusive collaboration to ensure equitable benefits and strengthened community engagement within critical mineral supply chains is one of the key themes identified in Chapter 4. The UK's critical minerals strategy emphasises sustainable mining practices and ESG standards, making it an attractive partner for responsible sourcing (UK Department for Business, 2023). The social upliftment of local communities is a stated priority for South Africa – and should be so for every organisation investing in its critical mineral mining activities – in accordance with the country's Bill of Rights, its endorsement of ESG principles and the UN's Sustainable Development Goals (SDGs), making community and indigenous participation central to its strategy. Furthermore, South Africa can learn from Canada's approach of ensuring that Indigenous communities benefit from mining projects with equitable participation in decision-making and revenue-sharing models (Canada Minister of Energy and Natural Resources, 2024).

6.2.4 Innovation and technology development

Aligning with another key theme outlined in Chapter 4, South Africa needs to invest in research and development (R&D) for alternative materials, recycling and processing technologies, focusing on strategies to enhance its technological resilience, foster innovation and ensure sustainable participation in critical mineral supply chains. The US and the UK both have made substantial investments in reducing dependency on specific critical minerals and enhancing recycling technologies (UK Department for Business, 2023; US Department of Energy, 2021). South Africa should prioritise R&D in key areas such as battery technology, alternative minerals and the circular economy to derive further value from progressing its critical mineral advantages (Montmasson-Clair et al., 2021; Moreno-Brieva & Merino, 2020). Organisations such as the Council for Mineral Technology (MINTEK) and the CSIR have a pivotal role to play in strengthening R&D efforts.

6.3 Theoretical framework integration

This research highlighted the importance of a well-developed CMS for South Africa, including the need for an integrated approach aligned with the theoretical framework provided. This framework, which emphasised stakeholder engagement, policy formulation and sustainable practices, underpins the development of a strategy that not only leverages South Africa's extensive mineral endowment but also aligns with global best practices.

The framework stressed the importance of comprehensive stakeholder consultation and robust policy frameworks in implementing effective critical minerals strategies. For South Africa, inclusive engagement with government agencies, industry leaders, local communities and regional partners is crucial to building trust, promoting social inclusion and ensuring equitable benefits from mining activities. Applying the criticality assessment methodology to identify essential minerals for economic and technological advancement is also essential.

South Africa will need policy and regulatory support in place to implement a sustainable CMS, as well as a culture of technological innovation and R&D for diversifying mineral use and ensuring long-term sustainability. Regional collaboration will also be crucial for fostering a robust, interconnected mining district that strengthens the supply chain and boosts regional economic growth.

Figure 6 presents the theoretical framework proposed by this study, populated with summarised insights and key details it addresses. This graphical representation serves to encapsulate the study's findings while illustrating the practical application of strategic theory. By bridging theoretical constructs with empirical observations, the framework offers a clear depiction of the study's learning outcomes and their alignment with the principles of strategy formulation and implementation.

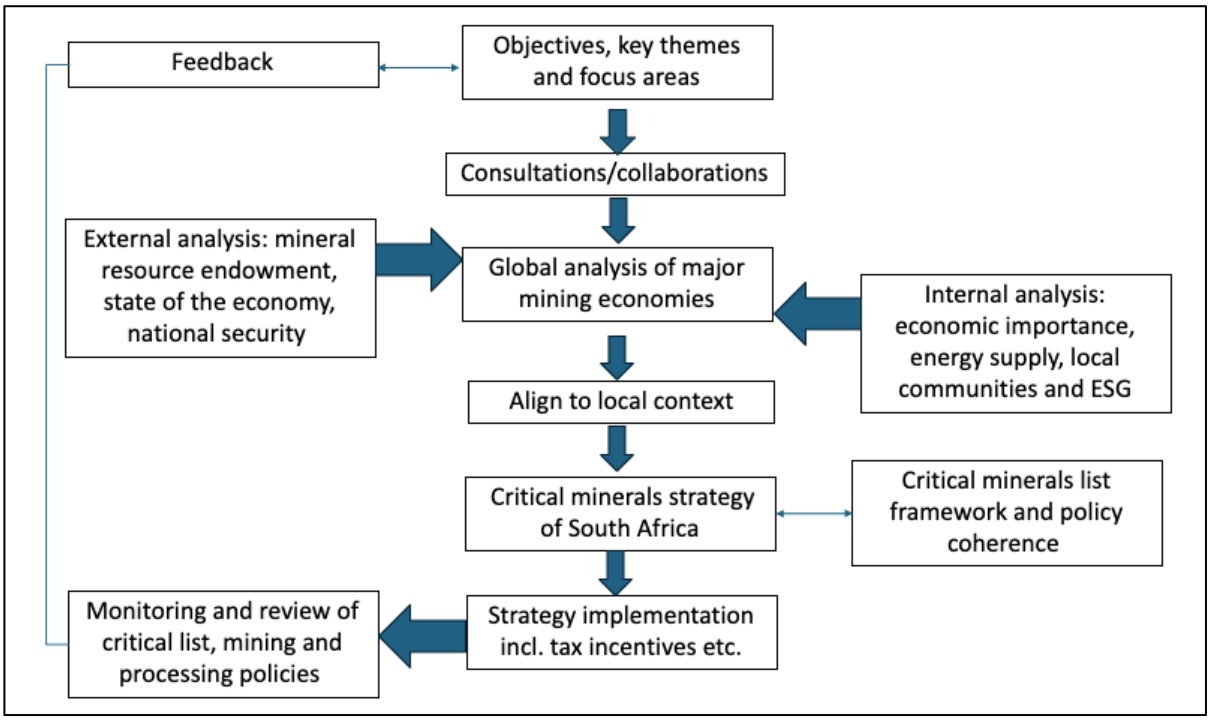

Figure 6. Theoretical framework and research objectives

In summary, the theoretical framework provided a structured approach that integrated stakeholder engagement, policy support, innovation and regional cooperation. South Africa's CMS should focus on enhancing exploration and

processing capabilities, embedding high ESG standards and fostering public-private partnerships to attract investment and drive sustainable growth. Continuous review and adaptation, informed by technological and market developments, will ensure that the strategy remains responsive and effective.

CHAPTER 7. CONCLUSION

This study aimed to make significant contributions to both academia and policy by presenting a structured approach to developing a CMS tailored to South Africa's unique socio-economic and geopolitical context. By synthesising global best practices from the USA, UK, Canada, Australia and India, it provided a comprehensive framework for South Africa to strategically manage its critical mineral resources. The study's integration of theoretical insights, policy analysis and stakeholder engagement aimed to contribute to the academic discourse on resource governance while offering actionable recommendations for policymakers to secure and optimise critical mineral value chains.

7.1 Implications for South Africa's economic transformation and the global energy transition

The findings of this study underscored the transformative potential of a well-developed CMS for South Africa's economy. By leveraging its vast mineral endowment, South Africa can diversify its economy, reduce reliance on coal and stimulate industrialisation through value addition and domestic beneficiation. The proposed CMS also aligns with global efforts to secure critical mineral supply chains essential for green technologies, such as electric vehicles, renewable energy systems and battery storage. These advancements would not only position South Africa as a key player in the global energy transition but also support the creation of jobs, infrastructure development and regional collaboration, thereby driving inclusive economic growth.

However, achieving these outcomes requires that the country address policy incoherence, foster stakeholder trust and ensure that mining practices meet high ESG standards. The study highlighted the importance of integrating ESG considerations into South Africa's CMS to attract sustainable investments and maintain competitiveness in international markets.

7.2 Future research directions

While this study provided a robust foundation for developing South Africa's CMS, future research should focus on several critical areas. First, quantitative modelling of criticality assessments, including economic importance and supply risk, could refine mineral prioritisation and inform policy decisions. Second, longitudinal studies tracking the implementation of CMS frameworks in South Africa and other resource-rich nations could provide valuable insights into their effectiveness and adaptability. Third, the role of regional collaboration within Africa, particularly through initiatives like the African Continental Free Trade Area (AfCFTA), warrants further exploration to understand how regional integration can enhance collective bargaining power and infrastructure development.

Ultimately, this study provided a roadmap for South Africa to harness its mineral wealth responsibly and strategically. By aligning its CMS with global best practices and adapting to local realities, South Africa can lead the way in shaping a sustainable, inclusive and economically transformative future in the critical minerals sector.

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9. APPENDIX A: Instrument

9.1 Document analysis

Document analysis is a valuable method in qualitative research, offering a way to conduct studies that may otherwise be challenging (Morgan, 2022). It is particularly useful for reducing ethical concerns and can be applied to various types of documents (Chanda, 2021). The process involved interpretative, comparative and integrative analysis, with the computer being a helpful tool in managing the work (Wester, 2004). However, it is important to be aware of the advantages and limitations of this method (Bowen, 2009).

According to Bowen (2009), Morgan (2022) and Wester (2004), the advantages of document analysis include its cost-effectiveness, ability to provide historical context and non-intrusive method that doesn't influence the phenomenon being studied. It allows access to data that would otherwise be difficult to gather, especially when other methods like interviews are not feasible. However, limitations include potential biases in the documents themselves, limited availability of relevant documents and the challenge of verifying the authenticity and accuracy of the documents. The method also risks overreliance on available texts, which may not fully address research questions.

To address these limitations, researchers should consider the nature and forms of documents, the use of reflexive thematic analysis and epistemological approaches to document analysis (Bowen, 2009; Chanda, 2021). Furthermore, the rigorous application of qualitative document analysis is crucial for its credibility in political science research (Wester, 2004).

9.2 Primary documents

The primary documentation used for analysis consisted of critical minerals strategies for the USA, the UK, Canada, Australia and India as listed in the main report.

9.3 Themes for analysis

The following examples illustrate the themes that were examined: background and context, strategic objectives, collaborating/contributing agencies, action plan incorporating key performance indicators (KPIs) such as timelines and budget, policies relevant to the implementation of the action plan, and monitoring.

10. APPENDIX B: Data analysis

10.1 Identification of themes

The study's key themes were identified using thematic analysis, a widely accepted qualitative method for systematically interpreting text data. The process involved a detailed review of each country's critical minerals strategy to identify recurring patterns, priorities and policy approaches. These recurring elements were then grouped into broader themes based on their relevance to the study objectives.

10.1.1 *Selection rationale for each category*

- **National security**: critical minerals are indispensable for national security, as they are integral to defence systems, energy independence and economic resilience. This theme reflects how countries prioritise safeguarding mineral supply chains from geopolitical and supply risks (Australian Department of Industry, 2023; US Department of Energy, 2018).

- **Sustainability and ESG standards**: with increasing global emphasis on environmental and social governance, sustainability is a critical component in mining policies. This category highlights how countries incorporate environmental protection and ethical practices into critical minerals development (Canada Minister of Energy and Natural Resources, 2024; UK Department for Business, 2023)

- **Indigenous and local partnerships**: countries like Canada and Australia have emphasised the importance of engaging Indigenous and local communities in mining activities, ensuring equitable benefits and reducing socio-political conflicts (Australian Department of Industry, 2023; Canada Minister of Energy and Natural Resources, 2024)

- **Diversification of supply chains**: geopolitical tensions and dependence on dominant suppliers (e.g., China) have driven efforts to diversify supply chains. This category captures policies aimed at reducing vulnerabilities through domestic production and international partnerships (Indian Ministry of Mines, 2023; US Department of Energy, 2021)
- **Innovation and technology**: investment in R&D is critical for advancing recycling technologies, exploring substitutes and enhancing processing techniques. This theme reflects the technological advancements necessary to secure critical mineral supplies (UK Department for Business, 2023; US Department of Energy, 2021).

10.2 Coding and categorisation process

The coding process followed an inductive approach, allowing themes to emerge naturally from the data. The steps were as follows:

10.2.1 Step 1: Familiarisation with the data

The strategies were thoroughly read to understand their structure, objectives and key focus areas. Initial notes were taken on frequently emphasised concepts and language.

10.2.2 Step 2: Data coding

- **Open coding**: specific terms and phrases such as ‘national security’, ‘sustainability’, ‘indigenous engagement’, ‘supply chain’ and ‘technological innovation’ were identified in each document. Each occurrence was tagged with a descriptive code.
- **Axial coding**: the open codes were grouped into broader categories based on their interconnections using the groupings shown in Table 9:

Table 10. Code development for theme categorisation

Theme groups	Key phrases
National security	• Strategic autonomy • Defence systems • Energy independence • Geopolitical resilience • Economic development
Sustainability and ESG standards	• Environmental protection • Carbon neutrality • Social equity • Circular economy • Climate resilience
Indigenous and local partnerships	• Community inclusion • Equitable benefits • Indigenous rights • Reconciliation frameworks
Diversification of supply chains	• Supply chain • Geopolitical risk • Strategic stockpiling • International partnerships
Innovation and technology	• Technological innovation • Research and development

	• Recycling technologies • Substitution materials

10.2.3 Step 3: Categorisation

The codes were synthesised into the five overarching categories. These categories were chosen for their ability to comprehensively capture the key priorities of critical minerals strategies across the five countries. They were validated through iterative review and alignment with the study objectives.

10.3 Application to the data

The coded text was analysed for frequency and context. Each mention of a category was tallied to determine its prominence within each strategy. For instance:

- The USA strategy frequently emphasised **national security** due to its reliance on critical minerals for defence technologies (US Department of Energy, 2021).
- Canada and Australia highlighted **Indigenous and local partnerships**, reflecting their focus on equitable development and reconciliation with Indigenous populations (Australia Department of Industry, 2023; Canada Minister of Energy and Natural Resources, 2024).
- **Innovation and technology** emerged strongly across all strategies, demonstrating the importance of R&D in addressing supply chain vulnerabilities.

10.4 Themes table construction

The final themes table was constructed by aggregating the frequency of mentions for each category across the five strategies. These counts reflect the relative emphasis placed on each theme by the respective countries. For example:

- **National security**: the USA had the highest number of mentions due to its focus on defence and economic independence.
- **Sustainability and ESG**: the UK emphasised ESG standards strongly, aligning with its global leadership in sustainability practices.
- **Indigenous and local partnerships**: Canada and Australia led in this category, showcasing their commitment to inclusive development.

Table 11. Theme categorisation frequency results

Category	USA	Canada	Australia	UK	India
National security	15	12	14	9	10
Sustainability and ESG	10	15	16	14	12
Indigenous and local partnerships	2	10	13	6	8
Diversification of supply chains	12	14	15	11	10
Innovation and technology	18	17	20	12	16

10.5 Methodological rigour

To ensure the robustness of the analysis:

- **Triangulation** was used to cross-verify findings with official reports and academic literature.
- **Iterative refinement**: categories were refined iteratively to ensure they accurately captured the strategic priorities of each country.

10.6 Conclusion

The five categories represent the thematic pillars of critical minerals strategies across the USA, Canada, Australia, the UK and India. The coding and categorisation process ensured that these categories were derived rigorously and reflected the shared and unique priorities of these economies. The constructed themes table provides a clear, quantitative representation of how these themes are emphasised, offering valuable insights for developing a comprehensive critical minerals strategy for South Africa.

11. APPENDIX C: Criticality assessment

The process of determining mineral criticality can be structured into three distinct stages to ensure a comprehensive and methodical assessment (Indian Ministry of Mines, 2023; Watari et al., 2020).

11.1 Stage 1: Lessons from major mining economies

Table 6 shows the most common themes which the various countries used to assess minerals and identify which were critical for key themes/indicators as follows:

- **National security:** contribution to GDP and relevance to strategic sectors (Indian Ministry of Mines, 2023; Zhang et al., 2023)
- **Diversity of supply chains:** dependence on imports, geopolitical vulnerabilities and resource concentration (Niemczyk et al., 2022; US Department of Energy, 2018)
- **Innovation and technology:** use in green energy, defence and advanced manufacturing technologies (Concordel, 2024; Northey et al., 2023)
- **ESG, including Indigenous and local partnerships:** addressing mining's environmental impact and social equity (Hotchkiss et al., 2024; Szamałek et al., 2022)

This study outlines the methodology underlying criticality assessment formulas but does not implement these methodologies due to the extensive data collection required, which lies beyond the scope of the research. Criticality assessments typically involve evaluating minerals against multiple indicators as listed above, which can be weighted and scaled to derive a composite score (Jain, 2024; Josso et al., 2023)

Nwaila et al. (2024) have outlined that by applying a weighted scoring system, the various minerals can be ranked according to their criticality. This ranking can then be refined to produce a prioritised critical minerals list, potentially limited to a specific number of minerals based on factors such as national capacity to address criticality concerns, strategic priorities and resource management capabilities. The determination of a cutoff for the critical minerals list is dependent on context-specific considerations, including technological, industrial and policy imperatives (Zhang et al., 2023).

The process of assigning weights and scales to indicators introduced challenges. While formulas for ranking minerals are often scientifically rigorous, the assignment of weights to indicators is inherently subject to some degree of subjectivity or bias. This subjectivity arises partly because indicators such as supply risk, economic importance and substitutability are interdependent, creating complexities in assigning appropriate weights (Nwaila et al., 2024; Zhang et al., 2023). For instance, a mineral with high economic importance might exhibit correlated risks in terms of limited substitutability or supply disruptions, complicating the isolation and independent weighting of these factors (Indian Ministry of Mines, 2023).

Nwaila et al. (2024) further outline that the interplay of qualitative and quantitative factors implies that criticality assessments are not purely data-driven exercises but also involve interpretative judgment. Thus, while these methodologies provide structured frameworks for evaluating mineral criticality, their application must acknowledge the inherent complexities and potential for subjective influence, particularly in assigning weights and determining scaling factors.

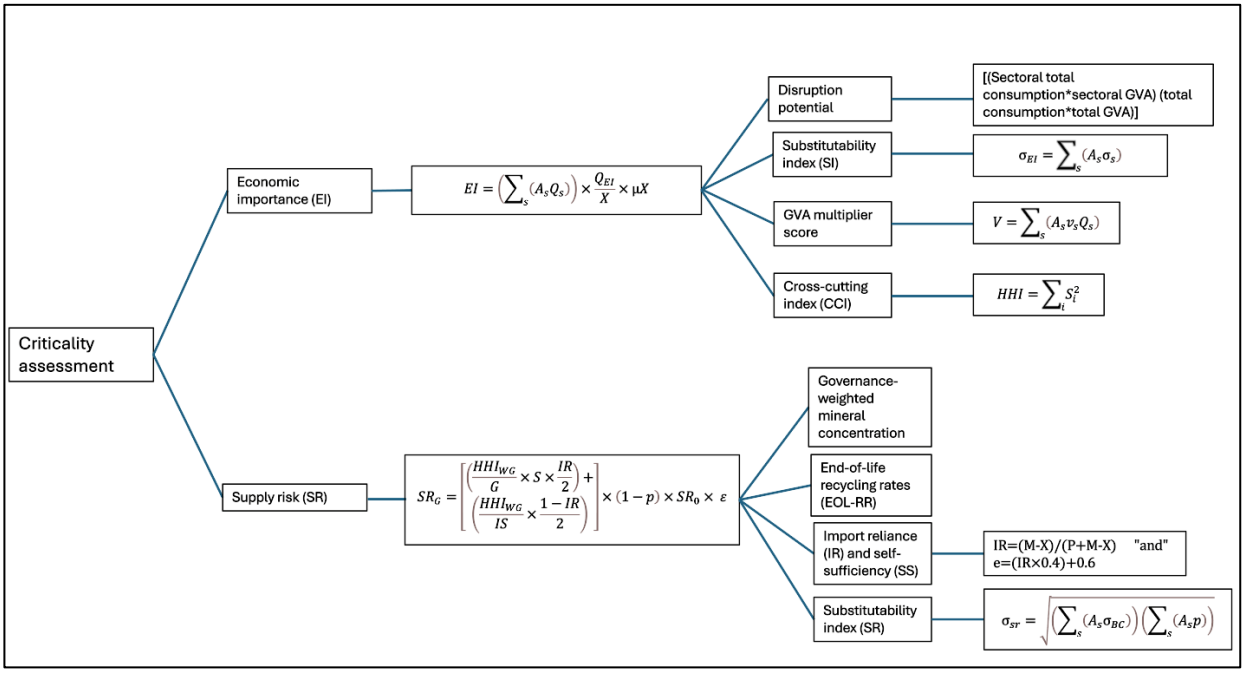
Definitions and criteria differ across nations due to unique policies and priorities, resulting in varied components and weighting in criticality assessments (Hayes & McCullough, 2018). These definitions underscore the complexity of mineral policies and their adaptation to national interests (Hotchkiss et al., 2024; Watari et al., 2020).

Below are two examples of formulas commonly applied in criticality assessments. The first example, proposed by Nwaila et al. (2024), calculates the economic importance (EI) score, one of the five key indicators in their framework. The second example, developed by the Indian Ministry of Mines and adapted from the EU methodology, evaluates criticality using two primary indicators: economic importance and supply risk.

Equation 1. *Relative economic formula*

Relative economic importance score = Value of production of CRMs / Total value of production of all CRMs

Equation 2. *Economic and supply risk formula*



11.2 Stage 2: Input from critical list collaborators

The collaborators in this process would include the aforementioned government departments, mining operators, civil society organisations and thinktanks outlined in the stakeholder engagement section. While essential for ensuring inclusivity and comprehensive input, this collaborative process is inherently time-consuming

and could result in an extensive list of priorities (reflecting the diverse interests involved). Given these constraints, it is recommended that this step be temporarily deferred in favour of the subsequent step discussed in this chapter, which offers a more streamlined approach to advancing the framework (Mathetsa et al., 2023; Montmasson-Clair & Patel, 2024).

11.3 Stage 3: Synthesising information to produce a CMS framework

Drawing from the definition of critical minerals outlined in South Africa's *2022 Exploration Strategy (DMRE, 2022)* and best practices from the five major economies analysed as case studies, a proposed critical minerals list for South Africa is presented in Table 8. This list incorporated minerals that, while not part of the original exploration strategy, are deemed critical by multiple major economies in the study. Notably, this proposed list includes coal, which is absent from the critical mineral lists of the other economies but is critical for a just energy transition (Blissett, 2023; Presidential Climate Commission of South Africa, 2022). The final compilation identifies 38 minerals as critical, with 14 already featured in the 2022 exploration strategy document.

12. APPENDIX D: Ethics Clearance

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School Ethics Committee

10/07/2024

Ethics clearance number: **WBS/BA9604564T/573**

This letter is only valid with a legitimate ethics clearance number and signed by the Researcher (below).

RE: Mr. Gudani Sivhabu

To whom it may concern

Mr. Gudani Sivhabu (9604564T) is currently registered as a MBA (Research Article) student at the Wits Business School, University of the Witwatersrand, Johannesburg.

This letter is to confirm that, at the time of writing, Gudani Sivhabu does not need ethical clearance for the study entitled:

Towards a critical minerals strategy for South Africa

This decision has been reached based upon a description of the project supplied by Gudani Sivhabu to the Wits Business School Ethics Committee, constituted as a subcommittee of the University Human Research Ethics Committee (Non-Medical), which has been evaluated by the subcommittee chair. This decision has then been ratified by the University Human Research Ethics Committee (Non-Medical).

If, however, Gudani Sivhabu changes the methods of data collection and analysis for this project, this decision may no longer be valid. If such changes take place, this should be communicated to the Wits Business School Ethics Committee.

Please feel free to contact me or the supervisor should you require any further information.

Yours sincerely,

Ethics Chairperson
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Supervisor:
Dr. Mathetsa
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Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I undertake to resubmit the protocol to the Committee.

GSivhabu
Signature

15 July 2024
Date: