Gordon Institute of Business Science
University of Pretoria

USING THE MULTILEVEL PERSPECTIVE FRAMEWORK TO UNDERSTAND THE TRANSITION OF SOUTH AFRICA'S MINING SECTOR TO A CIRCULAR ECONOMY

Dheepak Maharajh
19385715

A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in the partial fulfilment of the requirements for the degree of Master of Business Administration.

01 December 2020

ABSTRACT

The mining sector by its nature has historically been characterised as an extractive industry with a “take, make and dispose“ approach to mineral resources and the ecosystems within which they are located. Escalating environmental degradation is, however, putting pressure on the sector to remediate their legacy waste stockpiles and implement the principles of the circular economy. The latter is a framework that could transform the global practices from “cradle to grave” to a more sustainable “cradle to cradle” approach. The transition to a circular economy in the South African mining sector is, however, unclear. Using the framework of the multilevel perspective (MLP), this study has profiled the awareness of, and progress towards, the sector’s adoption of the circular economy principles and has suggested a way forward that could support an accelerated transition towards a circular economy business model.

A qualitative, inductive research method with purposive sampling was employed. Twelve semi-structured interviews were conducted using online platforms. The interviewees, comprised of a mixed group of business practitioners, content experts, consultants, and government officials, were questioned on their understanding and awareness of the circular economy, its status, the barriers and the enablers.

The analysis has revealed that the circular economy in the mining sector is still at an early stage. Whilst landscape pressure on the existing socio-technical regime is evident, the incumbents of the regime see more barriers than drivers to the transition and consider the transition to be of low priority within the present operations. Moreover, actors at the niche level, such as entrepreneurs and emerging firms, are weak and do not place any significant competitive pressure on the current regime. Particularly, networking of the niche actors, which is an essential development if these actors are to challenge the regime, is limited.

The transition of the mining sector to a circular economy framework will require more direct government intervention at the level of the landscape, such as regulatory reform; greater entrepreneurial activity; and a more focussed approach to strategic niche management. Initiatives such as the Green Engine, driven at present by Anglo American, could form a model for upscaling niche experiments and radically increasing the competitive pressure on the sector as a means of accelerating the transition.

KEYWORDS

Circular economy, sustainability, multilevel perspective, mining, mine waste

DECLARATION

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

____

Dheepak Misser Maharajh

1 December 2020

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

SA: South Africa, South African

MFA: Material Flow Accounting

CE: Circular Economy

SDG Sustainable Development Goals

EMF: Ellen McArthur Foundation

MLP: Multi-level perspective

GDP: Gross Domestic Profit

BCE: Before Common Era

ASARCO: American Smelting and Refining company

MPRDA: Mineral and Petroleum Resources Development Act, 28 of 2002

MHSA: Mine Health and Safety Act 1996

NEMA: National Environmental Management Act 1998

BLM: Bureau of Land Management

AEMA: American Exploration and Mining Association

EITI: Extractive Industries Transparency Initiative

MMSD: Mining Minerals and Sustainable Development

ICMM: International Council on Mining and Metals

10PC: 10 Principles for Change

7Qs: 7 Questions to Sustainability

FFRM: Framework for Responsible Mining

NRC: Natural Resource Charter

MMSD10+: Mining and sustainable development (MMSD10+)

SNM: Strategic Niche Management

TM: Transition management

TIS: Technological Innovation Systems

TEP: Techno-economic Paradigm

MBA: Masters in Business Administration

CHAPTER 1. INTRODUCTION TO THE RESEARCH PROBLEM

1.1 Introduction

From the advent of the first industrial revolution, industrial production has driven global economic growth and transformed national economies (Vries, 1994). Today, however, industries operate within an increasingly competitive and interconnected world, and must also adapt to the immediate needs to sustainability and a low carbon transformation. The rapid growth of the last century has strained the world's natural resources and the global population is now living beyond its sustainable footprint (Ellen MacArthur Foundation, 2013). Many researchers have looked at the Circular Economy as a potential solution to these resource-constrained issues (Balanay & Halog, 2016; Esposito, Tse, Soufani, 2018; Zhao, Zang, Li,Qin, 2012). This study focuses on developing an understanding of the enablers and barriers to the implementation of the Circular Economy in the South African mining sector.

The "take, make and dispose" philosophy of the archaic linear economy (de Jesus & Mendonça, 2018) has embedded an unsustainable mind-set for centuries that culminated in the resource crunch of today (Ellen MacArthur Foundation, 2013). The mining sector of South Africa (SA) is considered one to the most unsustainable industries in the world due to the entrenched linear economy model (Barr, 2014). For the mining sector to minimise its impact on the environment, continue to deliver on the growing demand for resources as well as grow the economy and create jobs, there is an urgent need for a shift to a focus on the circularity of resources and material flow accounting (MFA) (Lèbre, Corder, Golev., 2017b).

1.2 The Background to the Problem

The current disregard for the environment is placing immense pressure on global natural resources (Esposito et al., 2018). The natural resources required to power the needs of the growing population are depleting at a rapid rate and the impact of centuries of industrial activity is taking its toll on the planet. The waste generated by Earth's people and the archaic industrial processes that encouraged a "take, make and dispose" mentality has resulted in the landscapes of all countries scattered with large stockpiles of waste (Kinnunen & Kaksonen, 2019).

As resources deplete and the gap between the supply and demand widen the financial impact of linear economic principles become more apparent. Humankind is now becoming cognisant of the fact that we need to be more sustainable in our approaches to production and business at large (Bichueti, Gomes,Kneipp, Motke, Perlin, Kruglianskas, 2018). This realisation has led to countries placing more emphasis on the environment by reducing the non-sustainable nature of human impact and introducing measures such as triple bottom line reporting for businesses.

In response to the triple bottom line, many researchers have focused efforts on looking at mechanisms to mitigate the sustainability impacts of the traditional business practices (Balanay & Halog, 2016; Lèbre, Corder, Golev, 2017a; Mathews & Tan, 2011; Zeng, Mathews, Li, 2018). This increased research focus of the past few decades have given rise to models and frameworks such as the Circular Economy (CE), Sustainable Development Goals (SDG) and Eco-Innovation (Florin et al., 2015). The Circular Economy as described by the Ellen McArthur foundation (EMF) is a “concept that decouples the impact of finite resources on business and aims to design out wastes from systems and transitioning to renewable energy” (Ellen MacArthur Foundation, 2013).

The Circular Economy is principled on natural biological concepts where in a natural ecosystem there is no ”real” waste since the waste of one biological system is utilised by another (Van Driesche, Carruthers, Center, Hoddle, Hough-Goldstein, Morin, Smith, Wagner,Blossey, Brancatini, Casagrande, Causton, Coetzee, Cuda, Ding, Fowler, Frank, Fuester, Goolsby, Grodowitz, Heard, Hill, Hoffmann, Huber, Julien, Kairo, Kenis, Mason, Medal, Messing, Miller, Moore, Neuenschwander, Newman, Norambuena, Palmer, Pemberton, Perez Panduro, Pratt, Rayamajhi, Salom, Sands, Schooler, Schwarzländer, Sheppard, Shaw, Tipping, van Klinken, 2010) This concept of emulating nature is known as biomimicry (Dicks, 2016). Circular Economy has become a mainstream initiative to foster sustainable business and environmental impact, with many countries implementing policies on the circularity of resources and the Circular Economy (Bechtel, Bojko, Völkel, 2013). China was the first to formalise the government’s stance on the Circular Economy by proclaiming it into law, as a central development goal (Mathews & Tan, 2011). The EMF has been leading the research into the circular economy and have formulated a model (Figure 1).

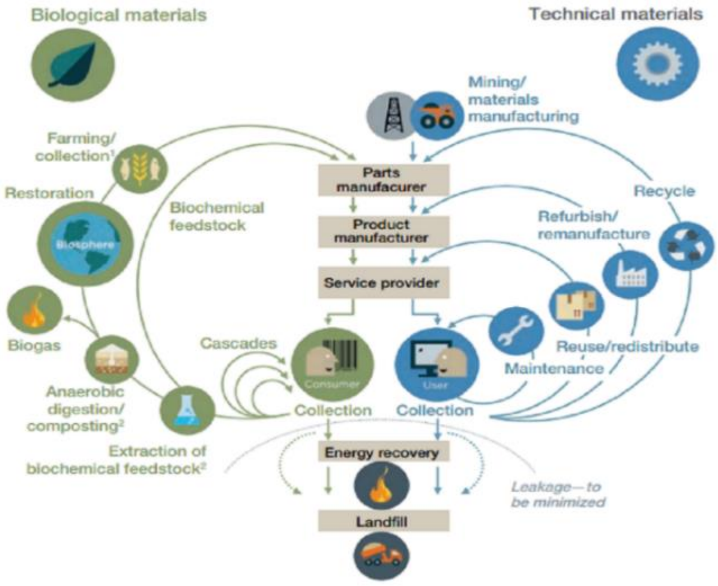

Figure 1: Circular Economy concept Source EMF (2013)

1.3 Implications for the Mining Sector

The mining sector is the producer of primary mineral and metal resources and have been doing so for centuries according to linear production principals. This has led to the rapid depletion of the resources, e.g. Oil is currently expected to be depleted by 2050 (Gumbo, 2013) and in SA, our gold mines have already started to reach depletion with consequential financial pressue (Neingo & Tholana, 2016). Within diminishing resources, the cost of extracting these resources become increasingly difficult and costly, resulting in austerity measures being deployed by the mining companies.

Environmental impact of mining and minerals processing has been the frustration of environmentalists, government and mining companies alike. The impact mining has on our water, natural resources and general landscape is a huge concern. Mining companies are investing large amounts of funds to try to deal with these problems. However, historically, dealing with environmental issues has always been viewed as a mandatory requirement placed by the government and it is only over the last decade and half, that miners have started to take this responsibility as a mechanism to make real impact. The Circular Economy has presented an opportunity to the mining sector to transform into a more sustainable and socially responsible organisation.

The South African mining sector has been slow to adopt the Circular Economy approach to mining and the lack of legislation to drive this, is exacerbating delayed commitment (Matinde, Simate, Ndlovu, 2018). South African mines are rapidly reaching exhaustion and the financial, social, and environmental impact of this can be significant

1.4 Purpose of the Study

Environmental impact research has focused efforts largely on the direct consequence of mining on the environment with little focus on the business sustainability. The main objective of this study is to establish the current status of the mining sectors transition to the Circular Economy and what are the enablers and barriers to its adoption.

1.5 Academic Justification

The theories of sustainability transitions have gained significant attention in the recent years and have provided several frameworks and models for the evolution and management of transitions (Gaziulusoy & Öztekin, 2019; Geels, 2002, 2011; Jackson, Lederwasch, Giurco, 2014). The Multi-Level Perspective (MLP) is a framework introduced by Rip and Kemp (1998) and refined by Geels (2002).

This study will focus on the application of sustainability transitions theory in understanding the adoption of circular economy principals in the mining sector. The specific frameworks related to MLP (Geels, 2002, 2011; Jackson et al., 2014) will be applied in this study to provide context to the landscape (macro-level), the regime (meso-level) and niche-innovations (micro-level) of the mining sector.

1.6 Business Rationale

The study will provide perspective of what are the current implications of linear economy on the mining sector and provide an understanding of where the industry is in the transition to the Circular Economy. This will allow for the establishment of processes, collaborations, and government initiatives to streamline the transition as well as exploit the multitude of business opportunities to improve the financial and environmental sustainability of the industry.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The opening chapter provided a basis for the study by detailing the problem and its implications to the business and academic progress. In this chapter a detailed assessment of the available literature is provided as well as the stipulation of the context to the circular economy. The literature review is based on a thorough review of circular economy literature as well as mining and waste management literature. The chapter provides a basis in history related to mining before discussing sustainable mining references. The implications of waste in mining and the related linkages and its environmental impacts are assessed. The circular economy concept is detailed, and the current projects related to circular economy are then discussed. The theoretical framework of the Multilevel Perspective is introduced before the gaps in the literature identified.

2.2 Mining History and Evolution

The extraction of resources from the earth dates to prehistoric times, with first mining being in southern Africa for coal. Since then then need for resources has resulted in the humanity searching the depths of the earth's crust for minerals to support our insatiable desire for growth. Over 20 000 years ago the first mining of minerals were recorded in southern Africa, however it was more than 10 000 years later that the modern civilisation expand mining activities to develop their needs for tools, weapons, pottery, jewellery etc. (Kitahara-Frisch, 1978). Egyptians were mining copper as far back as 3 000 BCE (Lucas, 1927) and the use of stone tools and weapons date back almost two million years (Kitahara-Frisch, 1978). It was the Egyptians who smelted gold and silver to produce jewels from ore for the Pharaohs (Johnson, 1999). These finding suggest that mining has been an intrinsic part of human history since the dawn of time and has been central to growth throughout our existence.

Since the 19th century the mining sector has been the driver of economic activity in the world and has been feeding man's desire for growth, improvements in lifestyle and transition to newer technologies. Currently the mining sector drives over 45% of global Gross Domestic Profit (GDP) (Creamer, 2012) and provides employment for a modest amount of people in countries where mining is a key GDP contributor.

2.3 Sustainable Mining

The earliest reference to sustainable mining in literature can be attributed to the 1987 Brundtland commission (Hueting, 1990), which was the start of the sustainable development goals by the European Commission and was led by the ex-prime minster of Norway, Gro Harlem Brundtland. As part this commission, sustainable development was defined as " the ability to meet present needs without compromising the needs of future generations" (Gorman & Dzombak, 2018). Sustainable mining on the other hand was first described by Allan (1995) as a concept that aims to reduce any negative impacts of mineral extractions from the ground on communities, environment and the economy. He further suggested that this must be done at a rate that does not create a deficit of the mineral when taking recycling, substitution minerals and new sources into consideration. In a review of sustainable mining Gorman & Dzombak (2018) distilled the various literature definitions and suggested one that agreed with Allan (1995) on the preservation of the environment, resources and social-economic factors, but added the health and safety of mine employees.

Developed countries consume far more mineral resources than the developing world (Kesler, 2007) and at the current rate of consumption society is going to need the equivalent of two earths to meet the future demand (Esposito et al., 2018) and with the shift to open pit mining, the generation of waste has increased. These combined problems has led to an increased interest in sustainability in the mining sector, although sustainability is not well associated with the mining sector because of the removal of resources (Parameswaran, 2016). Gorman & Dzombak (2018) identified two key schools of thoughts that dominate sustainable mining literature, basing their conclusions on the assessment and critique of numerous published works. The first was on improving extractive mining sustainability and was centred on the preservation of the environment. The other focus area was based on a more contemporary view that didn't limit its intervention to the mined resources or the process, but took a more holistic view of the circularity of the resource through its entire life cycle.

In a case study on American Smelting and Refining company (ASARCO), Gorman & Dzombak (2018) demonstrated how the mine was able to recycle over 80% of it process water and through a series of equipment and process changes, the energy usage was also reduced by an estimated 5,786,595 KWH (Parameswaran, 2017). A further intervention of ASARCO towards the sustainability goals was the inclusion of a 35 MW solar energy project that created 200 jobs (Gorman & Dzombak, 2018;

Parameswaran, 2017). The initiative also included the use of bio-solids from a nearby wastewater treatment plant to upgrade tailings to support vegetation. This project demonstrated that it is indeed possible to derive sustainable benefit for all three aspects of the triple bottom line in business.

2.4 Mining Waste

According to the National Environmental Management: Waste Act (NEMA: Waste Act 59 (2008), 2009), a waste is a substance that can or cannot be recovered, reduced, recycled or re-used and that:

- is excess, undesirable, rejected, thrown out, abandoned or disposed of;
- the manufacturer has no use for in the current production process
- must be treated or disposed of; or
- is identified as a waste by the Minister by notice in the Gazette, and includes waste generated by the mining, medical or other sector; but –
    - A by-product is not considered waste; and
    - Any portion of waste once re-used, recycled and recovered, ceases to be waste.

Waste material associated with mining is considered to be one of the largest contributors to all waste generated on the planet (Pactwa et al., 2020; Woźniak & Pactwa, 2018). The contribution of mining waste ranges from 15% to about 85 % with the hard coal mines being the largest generator of waste (Anawar, 2015; Gorman & Dzombak, 2018; Pactwa, Woźniak, Dudeket, 2020). Mine waste can be in liquid, solid or gaseous forms.

Table 1 below provides a high-level view of the current waste material in the mining sector.

Table 1: Mining waste materials

Type of Waste	Description
Overburden	The material that is removed during mining to access the valuable ore. It can cause secondary environmental issues like acid rock drainage.
Waste rock	Like overburden however waste rock does contain valuable minerals, however at very low concentrations.

Mineral beneficiation tailings	After the value minerals are removed through flotation of the fine material left over called tailings. This is a huge environmental problem due to dust pollution, risk of collapse as well as acid mine drainage. It contains residual minerals that generally are too low to extract economically
Metallurgical slags	During the smelting process to refine metals the glass-like material remaining are called slags. They are generally harmless to the environment but can contain toxic heavy metals
Wastewater	The largest contributor of waste and environmental harm from mining. Include mine drainage water, effluents, process water and leachates.
Water treatment sludge	The treatment of mine wastewater results in hazardous slurries, sludge's and brines contaminated with heavy metals and other chemicals.
Acid mine drainage (AMD)	Formed when the sulphide ores react with oxygen to form Sulphuric acids from waste rocks, tailings, wan waste coals. Acid mine drainage continues even post mine closure and often contaminates freshwater resources.
Gaseous and particulate emissions	These emissions are associated with the various high temperature processes in mining, producing toxic gases like SO_x, NO_x, CO, CO_2 and others

Source: Adapted from (Matinde et al., 2018)

What was disposed of as waste in the past is now being seen as an opportunity – a potential 'secondary resource'. Three resources are expected to play a role in the mining value chain, these are primary, the actual ore reserve; secondary, the recycled metals and minerals and enabling resources like water that drive the process (Sharma, Stelter, Davidson, Petersen, 2015).

The National Waste Management Strategy (Department of Environmental Affairs, 2011) was approved by Cabinet in 2011 and sets targets to promote waste minimisation, reuse, recycling and recovery of waste in South Africa. The Department of Science and Technology reported in the National Waste Roadmap (2013) that the waste sector currently employs approximately 29,000 people and is worth around R15 billion (0.51% of the country's GDP).

2.5 Environmental Liability and Responsibility

The right to mine in South Africa is governed by the Mineral and Petroleum Resources Development Act, 28 of 2002 (MPRDA). This is the dominating piece of legislation; however, a few other pieces of legislation must be complied with during the mining projects lifecycle. These include; Mineral and Petroleum Resources Royalty Act 2008; Mining Titles Registration Act 1967; Precious Metals Act 2005; Diamonds Act 1986; Mine Health and Safety Act 1996 (MHSA); National

Environmental Management Act 1998 (NEMA); National Water Act 1998 and the Spatial Planning and Land Use Management Act 2013. For the purposes of this study the key regulation of interest to this research is the NEMA act, as this act governs the waste management on mines and stipulates the liabilities and responsibilities of the mining companies (Swart, 2003). NEMA places responsibility on the mining rights holder for environmental liability, pollution or ecological degradation, the pumping and treatment of polluted or extraneous water and the management and sustainable closure of the mine (Davies, Berman, Pillay, Sonnenbergs, 2018). The NEMA act requires the mining companies to make pecuniary provisions for mine rehabilitation, this is done by a deposit, guarantee or a trust held by the government to ensure that the funds are available to rehabilitate the mine in the event of premature closure (Davies et al., 2018; Swart, 2003).

There has been numerous incidents associated with mismanagement of mines, disregard of the environment and the impact of waste materials left untreated (Chul et al., 2017; Rico, Benito, Salgueiro, Pereira, 2008; Sturdy & Cronje, 2014). In Spain on 25 April 1998, a tailing dam burst and spilt over five million cubic meters of hazardous sludge into the Argio River (Mullerat, 2000).

2.6 Circular Economy

2.6.1 The Origins of Circular Economy

The initial representation of a concept similar to the circular economy can be found in the book, *The Economics of the Coming Spaceship Earth* (Boulding, 1966). This was later refined and further developed by two environmentalists, Pearce and Turner (Ghisellini, Cialani, Ulgiati, 2016; Pearce & Turner, 1990). The first reports of policies on waste management related to Circular Economy was attributed to Germany, in 1972, with a waste disposal act that supported the model of holding the producer responsible (Geisendorf & Pietrulla, 2018). Industrial ecology is considered the home of circular economy theory as the available literature is mostly founder in these topics. It also represents a goal for industry that drives the notion of working within the environmental beneficial realm, fostering the circularity of resources and designing for zero waste (Balanay & Halog, 2016).

The first article on the Circular Economy immerged in 1918 and the next only published in the 1960's. From then until the new millennium, only limited works on the Circular Economy were published, however from 2010 there has been an explosion of literary works in this area with 2019 seeing over 2000 peer reviewed article alone (Figure 2). This representation of the growth in academic interest in the concept demonstrates the value of the Circular Economy in future sustainability research.

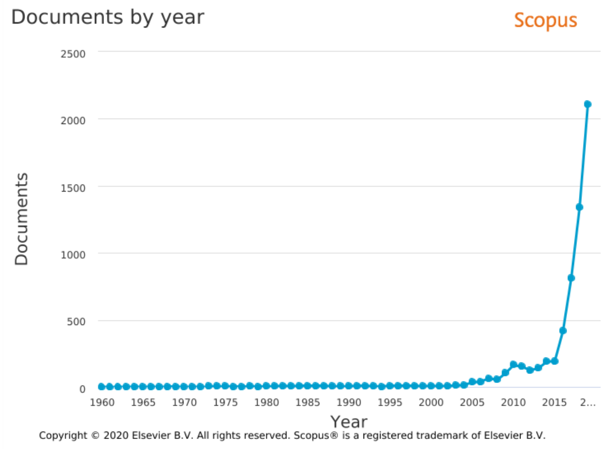

Figure 2: Circular Economy Publications per year

2.6.2 Definitions and Description

One of the most recognized definition is by Ellen MacArthur Foundation (2015): "A Circular Economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles." Esposito, Tse and Soufani (2018), on the other hand, explains that Circular Economy is about recycling, reusing and repurposing materials already in the system across the entire supply chain to enable the manufacture of different products. The Circular Economy has also been defined as a "closed-loop economy" that fosters a cradle to cradle approach to waste utilization within systems and processes (Geisendorf & Pietrulla, 2018). Circular Economy drives the efficient use of resources by supporting the transition from linear to circular use models (Ghisellini et al., 2016).

Woźniak and Pactwa (2018) defined Circular Economy in mining as the integration needed to improve the sustainability of mine operations to the extension of the life of the mined material. They further explain that Circular Economy in mining can address the needs of society as well the mining business operations.

2.7 Circular Economy Initiatives in Mining

The mining sector has significant socio-economic benefits, however, in its activities to generate value, it has caused substantial environmental issues such as disposal and stockpiling of large volumes of various solid and liquid waste streams (Kinnunen

& Kaksonen, 2019). In South Africa, tailings from gold mining are established to be 17.7 million tons (Matinde et al., 2018). Some of the environmental impacts associated with mining waste are acid mine drainage and heavy metal pollution of freshwater and groundwater resources as well as the instability of large mine tailings dams. (Kinnunen & Kaksonen, 2019). The mining sector is historically designed with linear material uses as opposed to circular ones, nevertheless, the concept of a circular economy can assist improve the sector's sustainability performance by solving the challenges of shortage of mineral resources (Kinnunen & Kaksonen, 2019; Tayebi-Khorami, Edraki, Corder, Golev, 2019).

The table presented below (Table 2) has been taken from (Balanay & Halog, 2016) as demonstrates some of the technologies implemented to deal with the various issues in the mining environment at the various levels in accordance with the 3R principle of the Ellen McArthur Foundation's ReSOLVE framework (Ellen MacArthur Foundation, 2015).

Table 2: Innovative technologies and approaches to Circular Economy in mining

Circular Economy Layers	Some Examples of Technologies and approaches
Enterprise (micro)	Facility and process engineering improvement (e.g., dry quenching and dry-de-dusting techniques for blast furnaces and converter flue gas, comprehensive use of water, flue gas and all solid wastes, regenerative combustion technology, gas recycling technology, blast furnace top gas recovery unit technology, sintering desulfurization, use of retorts, etc.) [Red, Rec, O, L]
	Mine water recycling [Rec, L]
	Mine water management [Red, O]
	Bioremediation [Red, E]
	Mine rehabilitation (e.g., progressive type) [Red, R]
	Shift to renewable energy and decarbonisation [Red, R]
Inter-enterprise (meso)	Mine waste re-utilization [Reu, S, E]
	Metals recycling [Rec, L]
	Heavy metals recovery (from tailings and mine water) [Reu, E]
	Structural adjustment (improvement in the industrial layout: regional industrial transfers and relocation) [Red, O]
Society (macro)	Dematerialization [Red, V]
	Extension of end of life (EoL) of products from mining [Red, V]

Note: [Red] Reduce; [Reu] Reuse; [Rec] Recycle (3Rs); [R] Regenerate; [S] Share; [O] Optimize; [L] Loop; [V] Virtualize; [E] Exchange (ReSOLVE Framework). Source:(Balanay & Halog, 2016).

Initiatives that embody circular economy principles are critical to successfully develop circular business models. A summary of the proceedings of the E3S web conference held in Finland in November 2014, found that there are some important initiatives related to circular economy in the mining sector (Pomykała & Tora, 2017).The European Union adopted a McKinsey report that detailed treatment of raw material in a manner that prevents it from impacting the balance of nature (Ellen MacArthur Foundation, 2013; Pomykała & Tora, 2017). These initiatives included closing the material circulation loop through projects in reducing consumption, designing leaner production processes, developing energy efficient processes and limiting environment footprints (Pomykała & Tora, 2017). The conference concluded that there is a need to identify an actor in the Polish mining sector who can subordinate the operating system in the mining sector to a circular economy model. This also led to the cohesion policy that was structured to support initiatives related to more recycling, bio-economy, energy efficient processes and other sustainability related projects (Pomykała & Tora, 2017).

2.7.1 Material Flow Analysis

Material flow analysis (MFA) is the qualitative and quantitative assessment of the material stock and losses within a value chain. MFA provides a critical tool that identifies areas where circularity can be improved and is also used by leaders within the ecosystem to position circular economy projects within the industry (Saidani et al., 2019). Lieder and Rashid (2016) conducted a detailed review of research perspectives related to the circular economy. They found that majority of the research was conducted in the resource scarcity and environmental impact areas. MFA was nestled under resource scarcity and the review revealed that a MFA study on the iron and steel industry was used to forecast production, recycling and consumption of iron ore (Lieder & Rashid, 2016). MFA models are reported to be a key enabler to socio-technical transitions and is therefore an important tool for progression to the circular economy.

2.7.2 Beneficiation of Waste Rubber from Mine Operations

Mines generate around 1333 m^3 of waste rubber from large earth moving truck tyres, conveyor belts and gumboots (Pienaar, Basson, Williams and Fordyce., 2019) and historically the rubber waste was sent to landfill or buried in the land, causing environmental damage. Waste rubber can however be recycled to other rubber products, combusted to generate energy or pyrolyzed to produce oil for the fuel industry (Toteva & Stanulov, 2020). This study also found that rubber recycling and combustion are amongst the most advanced waste handling technologies. The cement industry utilises a large amount of shredded tyres as an alternative fuel (Toteva & Stanulov, 2020). In South Africa a mobile rubber shredding business has emerged to fill the gap of legacy waste tyre treatment. Kabusha OTR process all sizes of tyres in the mining industry into rubber chips that are sold to the recycling industry. The technology takes roughly 30 minutes to process a tyre and is a useful circular economy project that is helping mines deal with their hazardous tyre and rubber stockpiles (Breytenbach, 2016).

Mining and mineral processing utilise inordinate amounts of fresh water in their operations and further contaminate even larger volumes of fresh water bodies from acid mine drainage (AMD) (Maharajh, Grewar,Neale and van Rooyen, 2018). The treatment of AMD to potable standards is extremely costly, however the passive biological treatment of AMD to a standard fit for reuse in agriculture, provides an excellent opportunity for water related circular economy initiatives. Mintek is actively demonstrating a biological AMD treatment technology in Emalahleni and are testing the treated waters application in agricultural irrigation projects (Maharajh et al., 2018). In a study to demonstrate internal reuse of process water, the authors highlight froth floatation as a major polluter of water. Reuse of internal process water was tested as a recycling method into the floatation process and revealed that there was no significant difference in the resultant concentrate when process water was recycled. A further benefit was reduced reagent dosage with recycled process water (Lin et al., 2020).

2.7.3 Urban Mining

Electronic waste (e-waste) is a rapidly growing waste stream that is a result of historic linear processes that accumulate over 40 million metric tons of e-waste annually (Krausmann, Wiedenhofer, Lauk, Haas, Tanikawa, Fishman, Miatto, Schandl, Haberl, 2017). The disposal of waste electronic products pose environmental issues and reuse is also not feasible, however the extraction of valuable metals from these products through urban mining is an option (Zeng et al., 2018). In this study the researchers found that the extraction of precious metals from e-waste is more financially feasible to new greenfield mining projects. However, the challenge to the implementation of e-waste urban mining is the effective development of hydrometallurgical processes to extract the metals of value. A study conducted in Singapore and Indonesia used MFA to demonstrate the potential of reuse of building materials through urban mining processes. They found that the reuse of building materials could help in the construction of over 1800 houses in 2016 (Arora, Raspall, Cheah, Silva, 2020).

2.7.4 The Green Engine and Impact Catalyst

The green engine is an early stage concept developed by Anglo Coal as an initiative to assist with sustainable mine closure through the establishment of circular economic models. This project has the potential to draw on multiple areas of environmental preservation technology to deliver circularity in the coal mining sector but also provides for effective mine closure that aligns to the sustainable development goals (SDG) to foster the circular economy. The project is part of the Mine Water Coordinating body (MWCB) of SA, which includes Eskom, Exxaro, Glencore, Sasol and South 32, representing the major players in SA's mining sector. The inclusion of this project in MWCB provides hope that this project can transition from a niche level Anglo Coal project to a regime level industry intervention. The green engine is an integration of different sustainability initiatives structured together to provide circularity and sustainability to the mining sector. The project further supports the upliftment and wealth creation of the communities surrounding the mines (Martins, 2017)

The impact catalyst is an initiative that is driven by the CSIR and consists of key partners from Anglo Platinum, Exxaro, World Vision, Zutari as well as the Limpopo provincial government. The project started as a mechanism for the Platinum mining sector to create new economic opportunities to be able to move labour from platinum mining to make way for mechanisation. However, it has morphed into a regional economic initiative that includes integrating projects on game farming, agro-processing, biodiesel, fresh produce markets and other sustainable development related initiatives (*Impact Catalyst*, n.d.).

2.7.5 Biomethane Production from Coal

The trading of coal generates large amounts of waste and discarded coal poses significant environmental liabilities to mining companies, power generating utilities and the government alike. The Department of Energy estimates that discard coal dumps accumulate at a rate of 60 million tonnes per annum and have already accumulated to an alarming level of two billion tonnes (Iannucci, 2008). Biogas is a well-researched source of energy and is generally obtained by the anaerobic digestion of biological waste organic matter such as food, animal and human excrement and other wastes (North, Engelbrecht, & Oboirien, 2015). Prof. Harpalani of the Southern Illinois University (SIU) has pioneered investigations into the use of waste coal as a feedstock for biogas production and has indicated (personal communication) that since waste coal is generally of small particle size, it makes an ideal feedstock for biogas production (Bi, Zhang, Park, Harpalani, & Liang, 2017b; Opara, Adams, Free, McLennan, & Hamilton, 2012; Pandey & Harpalani, 2018; Zhang et al., 2016). Methanogens are bacteria responsible for the anaerobic digestion of coal and other organic matter by converting H2 and CO2 to methane gas. Biogenic methane is generated when meteoric water penetrates coal seams to introduce the bacteria into anaerobic conditions. There are four stages involved in bio gasification of coal; hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Zhang et al., 2016)

2.7.6 Tailings Reclamation

The Johannesburg landscape is littered with remnants of the historic linear mining legacy, with tailings dumps posing significant environmental and social harm. Tailing are the fine crushed material that becomes waste after the valuable resources have been removed, however, these dumps still contain low levels of valuable metals in them, with estimates of 0.4 g of gold per ton of tailings material (Rösner & Van Schalkwyk, 2000). Tailing dams contain pyrite that generate AMD that cause immense environmental damage. There are currently 270 tailings dams occupying ~180km^2 of land. Rösner and Van Schalkwyk (2000) concluded that these tailings dams pose huge environemtnal threat to soil and groundwater due to the heavy metal content being higher than the acceptable threshold. Kinnunen and Kaksonen (2019) found in their study that although tailing benificiation was still in its infancy, the respondednt in their study viewed tails as an important furture source of minerals. Kimberlite tailings on the other hand have demonstrated to be important carbon capture and utilisation tool when used as a cement substitue in concrete brick making (Chakravarthy, Chalouati, Chai, Fantucci, Santos, 2020). The extraction of uranium, gold and platinum group metals in SA, Lead and Zinc in Zambia and Gold in Austrailia and Romania were demonstrated using mobile superconduction magnetic separators (Watson & Beharrell, 2006).

2.8 Barriers to Circular Economy Transitions

One of the challenges faced in the advancement of the materials circular economy is the management of hazardous or potentially hazardous substances that become embedded in material cycles (Bocken, Olivetti, Cullen, Potting, Lifset, 2017). Kinnunen and Kaksonen (2019) explain that one of the biggest challenges is the low concentration and mass of recoverable elements for economical processing. Investment costs of processing plants are high, and it takes time to break even. It was also noted that profitability requires certain scale of operations. Based on the interviews they conducted, the knowledge gap of the tailings as well as the understanding of the circular economy was also considered a significant barrier. Circular economy strategies require social and institutional changes, as well as business models and circular product design. Fundamental changes in the upstream processes of production and consumption need to be made, and therefore stakeholders through the whole production chain need to change their practices, and integrate related socio-institutional changes (Bocken et al., 2017).

Bechtel, Bojko, and Völkel (2013) resolved 165 barriers and only 56 drivers to the circular economy from interviews they conducted, Their study characterised the barriers under four categories viz; technological, legal, economic and change in mindset. The technological barriers were largely around the lack of enabling technology for recycling, while legal focussed on regulations and policy uncertainty that limit circular economy intiiaitves. Unders their economic category, the lack of a business case for circular economy projects were cited as a deviation from core business. The category of change in mindset was based on leadership disinclination to transcend traditional liner material flows into more sustainable circular economic paradigms.

In South Africa, the policy landscape and regulatory framework is further constrained by increased conrruption that undermines the regulations and policies that are protecting the environment and helping the circular economy transition (Ramos-Mejía et al., 2018). SA lacks a dedicated policy framework for the circular economy and currently the only policy document that makes reference to the circular economy is the Department of Science and Innovations (DSI) white paper on science, technology and innovation (DSI, 2019). Similar finding were decribed in research from Polland, Finland and other European countries (Bechtel et al., 2013; Kinnunen & Kaksonen, 2019; Woźniak & Pactwa, 2018). The regulatory barriers are not limited to developing economies but also across the western world. Examples are present in some European countries, where the utilisation of by-products are blocked because companies cannot supply firms outside the export zone (Mathews & Tan, 2011). In first world countries like Germany, Japan and United States, strict regulations are disincentivising firms from exchanging waste materials, a practice that is by design circular in nature (Mathews & Tan, 2011)

Financial resources are generally lacking globally and is worse when circular economy initiaitves and projects are positioned to investors (Bechtel et al., 2013; Ellen MacArthur Foundation, 2015). This problem is further exacerbated by the mining companies view that circular economy is outside of their core business and therefore do not consider related projects a priority (Barr, 2014; Bechtel et al., 2013; Dill, 2016; Tost, Hitch, Chandurkar, Moser, Feiel, 2018). Mining leadership are generally appointed for a limited time frame and therefore dedicate all their efforts to demonstrating shareholder return during their tenure. This means focusing on the mining sector's linear business principles and ignoring circular economy intiiaitives the latter more likely to demonstrate returns in the longer term when current leadership have moved on (Barr, 2014; Lèbre et al., 2017a)

2.9 Drivers, Benefits, and Enablers of Circular Economy

The global economy's evolution has been influenced by a linear model of production and consumption, whereby goods are manufactured from raw materials, sold, used and then discarded as waste. Several of factors indicate that the linear model is increasingly being challenged by the very context within which it operates. Factors such as economic losses and structural waste, prices risk, natural systems degradation, regulatory trends, advances in technology, acceptance of alternative business models and urbanisation. Regulators, in the recent years, have tried to curtail and price negative externalities. The number of climate change laws has increased by 66%. Carbon pricing, in the form of an emissions trading scheme or a carbon tax, has been implemented or is scheduled to commence in almost 40 countries and over 20 cities, states and regions. In Europe, 20 countries levy landfill taxes, which together raised revenues of €2.1 billion in 2009/2010 (Ellen MacArthur Foundation, 2015)

According to Esposito, Tse and Soufani (2018) primary materials used in construction, car manufacturing, synthetic fertilizers and pesticides, fuel and non-renewable energy, and land use, among other uses, can be replaced and recovered and materials repurposed in cascaded use.

Ellen MacArthur Foundation (2015) analysed the environmental and system-wide opportunities and benefits of EC. They have identified, that by adopting circular economy principles, countries could create tremendous opportunities for the industrial renewal, regeneration and innovation, economic growth, substantial net material cost savings and creation of employment opportunities. Table 2 summaries the tremendous opportunities that businesses and policymakers can enjoy if they transition to a circular economy.

Table 3: Opportunities and benefits of circular economy as identified by The EMF (2015)

Opportunities and benefits of CE	Examples
Environmental and system-wide opportunities	Reduced carbon dioxide emissions
	Reduced material consumption
	Land productivity and soil health
Economic opportunities	Economic growth, as defined by GDP
	Substantial net material cost savings
	Job creation potential
	Innovation
Opportunities for citizens	Increased disposable income
	Greater utility
	Reduced obsolescence
Opportunities for companies	Profit opportunities
	Reduced volatility and greater security of supply
	New demand for business services
	Improved customer interaction and loyalty

A number of favourable system conditions and enablers that can greatly help with the transition towards a circular economy are (Ellen MacArthur Foundation, 2015):

- Education: to prepare future professionals for a new economic model and to create the skill set to drive circular innovation
- Financing: All stakeholders across value chains will need access to financing and risk management tools to support capital investment and research and development (R&D).
- Collaborative platforms: Effective cross-chain and cross-sector collaboration will be needed for the large-scale establishment of a circular system.
- A new economic frame: Complementing today's flow-based metrics, such as GDP, with measures of a country's stock of assets, and developing a long-term plan to rebalance factor costs and adequately price key externalities.

2.10 Supporting Circular Economy Transitions

The Ellen MacArthur Foundation, through research and expert interviews have identified six mechanism that public and private institutions can use to aid the shift from linear to a circular economy. These are explained by the EMF (2015) to be the ReSOLVE framework, viz.: regenerate, share, optimise, loop, virtualize, and exchange. The implementation of the ReSOLVE framework suggests that extending products lifespans, utilising renewable resources and energy, re-purposing spent resources and minimising wastes will allow for the improvement of efficient management of waste (Balanay & Halog, 2016; Ellen MacArthur Foundation, 2015). Balanay and Halog (2016) eloquently allocated the aspects of ReSOLVE to the product life cycle.

China was one of the first nations to implement legal guidelines for a Circular Economy and their policy supports the 3Rs (reduce, reuse and recycle) to support process interventions and new manufacturing processes that reduce or exclude waste generation. Analogous to the aforementioned model, is the layered Circular Economy model from China (Balanay & Halog, 2016), which provides simple guidelines to transition to a Circular Economy. The layers as explained in the framework align to the MLP initially presented by Rip and Kemp (Rip & Kemp, 1998) and brought into mainstream sustainability transitions literature by Geels (Geels, 2002, 2011, 2020). These layers relate to the industrial enterprise (micro), inter-enterprise (meso) and the societal (macro) levels in an effort to design wastes out and close the loop (Balanay & Halog, 2016; Geels, 2002, 2011). The Balanay and Halog (2016) literature appears to adopt the MPL framework presented by (Geels, 2002; Rip & Kemp, 1998; Schot & Geels, 2008), however neither of these MLP research work is referenced or acknowledged.

Gorman and Dzombak (2018) assessed the environmental sustainability in mining by using several frameworks and standards such as the Bureau of Land Management (BLM), American Exploration and Mining Association (AEMA), Extractive Industries Transparency Initiative (EITI), Mining Minerals and Sustainable Development (MMSD), International Council on Mining and Metals (ICMM) 10 Principles for Change (10PC), 7 Questions to Sustainability (7QS), Framework for Responsible Mining (FFRM), Natural Resource Charter (NRC) and Reflecting on a decade of mining and sustainable development (MMSD10+). They noted that environmental performance characteristics categorized into four elements: reduction of inputs (water, energy and reagents), minimization of land disruption (soil erosion, preserve biodiversity), reduction of outputs (greenhouse gases, mine waste and pollution) and responsible reclamation and rehabilitation of mine lands can be used to improve the sustainability of mining operations. 7QS and FFRM frameworks are the most ideal frameworks as they fulfil all the four elements of the environmental performance characteristics. The NRC and EITI are more focused on land management and the environmental responsibilities of mine closures. MMSD10+, MMSD, BLM, MA and 10PC frameworks are satisfactorily on all four elements. The BLM framework under reduction of inputs is more focused on the reduction of energy and emphasizes on recycling and reuse to develop sustainability.

A few different frameworks have been used to envision, understand and further the progress of transition towards the circular economy. Transition frameworks include the MLP on socio-technical transitions, strategic niche management (SNM), transition management (TM), technological innovation systems (TIS), techno-economic paradigm (TEP) shifts, and socio-metabolic transitions (El Bilali, 2019; Lachman, 2013).

2.11 The Multi-Level Perspective

The MLP framework was developed by Arie Rip and René Kemp (Rip & Kemp, 1998) and later refined by Frank Geels (Geels, 2002). The initial MLP framework described to comprise of micro, meso and macro levels, these corresponded to artefacts, technical systems and Mumfordian mega-machines (Rip & Kemp, 1998). This representation of MLP further explained that the adoption of technology is influenced by regimes which are generally have an irreversible component embedded in rules and routines in society. In 2002 Geels (2002) presented a refined model of Rip and Kemp's framework. In this he also described the MLP as having three levels that influence technology transitions or adoptions. He describes these levels as the landscape level (macro), which is extremely difficult change and are rigid structures. The regimes (meso) is described similar to that of Rip and Kemp (Rip & Kemp, 1998) and the rules help constrain and limit new technology adoption. The niche level (micro) is described as the level where radical innovations take place due to its relative isolation from regime level influences. The resultant relationship between these three levels is the MLP framework (Figure 3), which states that transitions come about through collaborations within and between three levels: niches, regimes, and a socio-technical landscape (El Bilali, 2019; Geels & Schot, 2007; Jackson et al., 2014).

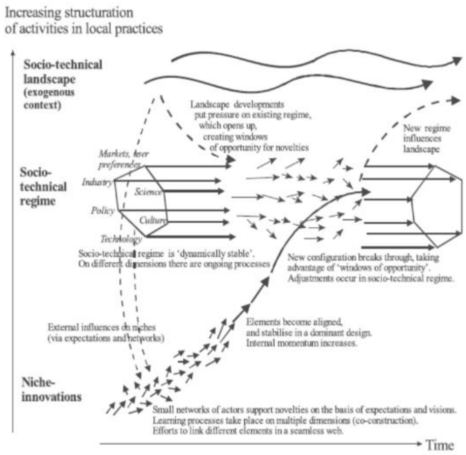

Figure 3: Diagrammatic Representation of the Multi-level Perspective (Geels & Schot, 2007)

2.12 Gaps in Research

The review of the literature has revealed a large number of works on the circular economy in a diverse range of economic sectors (Balanay & Halog, 2016; Dill, 2016; Essah & Andrews, 2016; Gorman & Dzombak, 2018; Packey, 2012) with the exception of the mining sector. Further to this, studies have not been undertaken to apply sustainability transition frameworks to understand where the reluctance to adoption lies. In this study, the application of the MLP framework to the implementation of the circular economy in the mining sector is evaluated as a means of developing a perspective as to whether the transition will be further sustained.

CHAPTER 3. RESEARCH QUESTIONS

This chapter details the research questions devised for this study that the researcher will aim to answer during the interviews and the analysis of data. Chapter two presented an extensive review of the literature which demonstrated a gap in the understanding of the circular economy in the mining sector of South Africa (Barr, 2014; Bechtel et al., 2013; Dill, 2016).

The MLP framework as presented by Geels (2002) will be used to develop an understanding of what fosters or hinders the adoption of the circular economy in SA. The MLP frameworks was previously used to evaluate the mining sector (Balanay & Halog, 2016) and the agricultural and food systems (El Bilali, 2019) of China. However, no prior research on the use of MLP in the mining sector of SA could be found. Therefore, the overall aim of this research was to determine the current influencing factors to the adoption of the circular economy in the SA mining sector using the MLP framework. The following key research question have been formulated.

3.1 Research Question One

What is the status of the Circular Economy transition in SA's mining industry?

There is a growing number of literary articles on circular economy, however the number of articles specific to the circular economy in the mining sector are limited. This question was devised to obtain an understanding from the interviewees on initiatives that they might know of, that are not currently in the public domain. This will enable the researcher to generate a broader view of the industry's current position on circular economy.

3.2 Research Question Two

What is hindering and/or driving a Circular Economy transition for SA's mining sector?

The circular economy is an emerging concept and there have been reports of enablers and barriers to the implementation of circular economy initiatives. This question aims to develop an understanding of what these specific barriers and drivers are, that influence the transition towards the circular economy in the South African mining sector. The answer to this question will provide an understanding of what needs to be addressed to aid the transition.

3.3 Research Question Three

Based on the MLP and sustainability transitions theory, what needs to change to accelerate the Circular Economy transition?

The Multilevel perspective is a theoretical framework used to explain socio-technical transitions and highlights the interventions required at the three levels of society, viz:

the landscape, regime and niche levels. This question is positioned to derive valuable insights on how to apply the findings from the question related to barriers and drivers, to hypothesise key mechanisms of transition of the mining sector towards a circular economy.

CHAPTER 4. RESEARCH METHODOLOGY

This study was positioned to develop an understanding of the circular economy and the mining sector. It aimed to identify initiatives currently active in the industry and determine barriers and drivers to the transition of the mining sector towards a circular economy. Previous studies have looked at the circular economy in the mining sector of different countries in the first world (Balanay & Halog, 2016; Gorman & Dzombak, 2018; Kinnunen & Kaksonen, 2019; Laurence, 2011; Pactwa et al., 2020). However, the industry perspective on the circular economy is not well articulated and therefore the study lends to a qualitative research approach. Ritzén and Sandström (2017), adopted a similar perspective for their study. Exploratory research is the best choice for studies were the concept being investigated is uncertain (Balanco, 2015) and in this case the mining sector's position on circular economy is not clearly understood, therefore the exploratory research approach was preferred.

The research methodology chapter will provide an overview on the direction of the study and the justification for the selection of the research approach. This chapter provides an overview of the methodology employed to answer the research questions formulated in Chapter three. It further explains the philosophy, population and selection criteria, the approach, measurement instruments and the limitations of the study.

4.1 Philosophy

The implementation of the circular economy has been described as a positive step for all industrial sectors (Ellen MacArthur Foundation, 2013; Florin et al., 2015), however it implementation in the mining sector is slow and random (ElFouly & El Aziz, 2017)(Bechtel et al., 2013; Gorman & Dzombak, 2018). This leads one to believe that there is some underlying hindrance to the implementation. The philosophy position taken for this study was one of critical realism. Critical realism is a philosophy that aims to explain the visible effects of what we uncover from research, by understanding the primary structures that impact this reality (Saunders & Lewis, 2018). This research aimed to develop an understanding of the underlying reasons for the current status of the circular economy in mining, thus a critical realism philosophy was an appropriate choice.

4.2 Approach

The literature available on studies of the circular economy have demonstrated close relations to the sustainability transitions, theoretical frameworks and the explanation of circular economy progress across multiple sectors (Balanay & Halog, 2016; Bechtel et al., 2013; Geels, 2011; Geisendorf & Pietrulla, 2018; Gorman & Dzombak, 2018; Jackson et al., 2014; Rip & Kemp, 1998). This allows for a deductive approach (Saunders & Lewis, 2018) that allows for the application of existing theoretical frameworks to evaluate the current status of the circular economy transitions in the mining sector. The existing theoretical framework of MLP was applied to this deductive study. Other researchers applied a similar deductive approach and application of frameworks during their research (Balanay & Halog, 2016; Kinnunen, 2019).

4.3 Techniques and Procedures

The study was planned to include a series of face to face interviews with a preselected set of interviewees, however with the onset of COVID-19 and implementation of social distancing, this approach was not possible. This resulted in the researcher conducting all interviews via the MS Teams online meeting platform. This technique for semi-structured questioning has emerged in a research study conducted during the COVID-19 pandemic (Vutha, 2020) as a consequence of the circumstances. Interviews were conducted against a set of prepared questions (Appendix II) and the details and responses provided by the interviewees were probed further to get clarity of understanding. (Dill, 2016; Saunders & Lewis, 2018).

4.4 Strategy

According to Saunders and Lewis (2018) a survey strategy is when a structured data collection is conducted using questionnaires or structured interviews, however Hofstee (2006) states that survey-based research “can range from highly structured to unstructured in-depth interviews” and this approach was used in other studies of the circular economy (Dill, 2016; Jackson et al., 2014; Kinnunen & Kaksonen, 2019). Therefore the strategy employed for this study was survey-based, which is considered suitable for exploratory studies in business management research (Saunders & Lewis, 2018).

4.5 Time Horizon

The research was conducted between September and November 2020 using a cross sectional study method (Saunders & Lewis, 2018). This method was found to be the most appropriate considering the short time frame available for MBA research studies.

4.6 Research Design

4.6.1 Population

The population is described as the "complete set of group members" (Saunders & Lewis, 2018) that share a common set of characteristics (Zikmund, Babin, Carr, Griffinet, 2012). In this study that population could therefore be interpreted as all the employees of the mining companies and associated consulting, R&D and government organisations in South Africa. The research sample for this study was taken from one of four categories; viz; business practitioners, content experts, consultants, and government officials. Dill (2016) employed similar categorisation of her interviewees. The business practitioner group were employees of mining companies and were responsible for some aspect of sustainability at the firm. The content experts were identified as any person with a track record of research in a field related to the study, these experts were from academia and research institutes. Although the senior management of mining companies were initially considered as samples for the study, their lack of availability and willingness to partake in the study prevented their views from being captured.

4.6.2 Unit of Analysis

The key aim of this study was to provide an insider perspective from individuals associated with the mining sector. The unit of analysis describes the entity or individual that provides the data for the study (Zikmund et al., 2012), and would therefore be the opinions and experiences of the people interviewed during the study. Therefore, the unit analysis for this study is described as the opinions, views and information provided by the interviewees. These individuals represent the mining sector and have some level of knowledge of the industry, including sustainability professionals within the mining sector of SA and knowledge experts in circular economy in academia and public sector.

4.6.3 Sampling Method and Size

A non-probability sampling technique is generally employed when the researcher does not have access to the full list of the entire population, does not bear statistical relevance to the population and is a suggested approach for qualitative semi-structured interviews (Saunders & Lewis, 2018). Participants for a qualitative study can be between five to fifty in number and are generally lower in number required for a quantitative study (Marshall, Cardon, Poddar, Fontenot, 2013). The sampling technique therefore chosen for this study will be a non-probability, purposive homogenous sample. A list of potential interviewees was compiled based on qualifying criteria determined to be anyone with a direct link to the mining sector either through employment, research association, consultancy, and related government departments. It proved extremely difficult to get access to majority of the people identified and the research had to follow a snowballing approach to reach the targeted number of respondents of 12. This range of responses is suggested as the point at which saturation is reached (Boddy, 2016). A similar sampling method was employed by Kinnunen and Kaksonen (2019) and Dill (2016).

4.6.4 Measurement Instrument

The objective of the study was to identify the status as well as the drivers and barriers to the circular economy in mining. To accomplish this objective, it was necessary to obtain key insights from key players within the mining ecosystem. A series of in-depth open-ended questions were posed to the respondents through a series of online structured interviews. The questions (Appendix II) were designed to allow the flow of conversation and to interrogate the industry through the interviewee's responses.

There are three key themes that the researcher aimed to gain insight into viz.; status of circular economy transition in mining, barriers to Circular Economy transition and drivers that will assist in the transition to a Circular Economy. The questions were designed to extract the valuable information that was categorised according to the research questions that encompassed these aspects. Through the interactive conversation with the targeted respondents the researcher was able to develop and understand the opinions of the interviewees. He was also able to interrogate and interpret this in line with the chosen MLP framework (Geels, 2002) in relation to how the interviewees proposed changes should be made to assist the transition.

4.6.5 Data Gathering Process

The data for this study was gathered through semi-structured interviews with respondents. The questions pertained to topics that the researcher intended to gather information on (Saunders & Lewis, 2018). The interviews were conducted over four weeks from September to October 2020 and respondents were contacted telephonically or via email to arrange suitable dates for the discussion. Prior to the interview the researcher emailed the informed consent forms (Appendix I) and the semi-structured questions to the respondents. Each interview took between 35 to 60 minutes and all interviews were recorded after consent from the respondents were obtained. Recordings were made using both the meeting recording tool on MS teams as well as on the researcher's cell phones. Recordings were downloaded on an external drive and the recordings deleted from the respective devices thereafter. Each interview was saved with a unique identifier that only the researcher could link back to the respondents' actual name.

All interviews were transcribed by an external contractor after an appropriate non-disclosure agreement (NDA) was signed (Appendix III). This NDA was to ensure the confidentiality of the participants. Transcription of the audio recordings were done verbatim and in English.

4.6.6 Data Analysis

The data collected from the interviews was analysed using an applied thematic analysis method (Guest, MacQueen, Namey, 2012). Audio files were transcribed into word documents and uploaded onto ATLAS.ti 8. Each interview transcript constituted a document in ATLAS.ti and as the researcher read and analysed the transcripts codes were assigned to issues that were frequently raised by respondents. A list of the codes used in the study can be found in appendix V. These codes were placed to code categories that aligned to themes that could be easily analysed under the three research questions.

The data was organised according to codes, code groups, as well as document groups. The document groups clustered the respondents into the four categories described under the population in 4.6.1 above. This structuring of the data made it easier to export code frequency reports, quotation reports and network diagrams from ATLAS.ti. These reports and diagrams were used to present the data in Chapter five.

A saturation analysis was conducted as presented by Balanco (2015) to assess the prevalence of new codes with new respondents by using frequency reports of the coded data. The first incidence of participant mentioning a new concept, and this was then not counted for subsequent participants and the total new codes emerging on this basis was totalised to present a graphical representation of saturation. Dill (2016) found that data coding sometimes influenced subsequent interviews and could increase the researcher's bias, therefore the researcher coded information once all interviews had concluded.

4.6.7 Validity and Reliability

The quality of the research conducted is assessed through validity and reliability of the findings and the research process (Thoka, 2020). Validity relates to the research quality and is assessed by the level of researcher bias that is present in the study (Saunders & Lewis, 2018; Vutha, 2020) and demonstrating a link between the researchers interpretation and interviewees responses. Reliability on the other hand is measure of the how reproducible the study is.

To address the issues of credibility the interview was not limited to the predetermined questions and respondents could state their views without being coerced. The researcher ensured that the questions posed to the interviewees were understood to ensure their accurate responses.

4.6.8 Limitations

Although a qualitative study is the correct choice for exploratory research, a limitation of the study is the lack of quantitative trends, life cycle analysis and material flow accounting data, that demonstrate the status of Circular Economy transition (Lèbre et al., 2017a). This is therefore a recommendation for future studies. Access to key individuals were a challenge and therefore the senior mine employees and executive leadership do not constitute the respondent categories.

The time pressures associated with an MBA study limited the number of respondents to 12 and to participants within the researcher's network that were willing to engage in interviewees. With added time the research would have preferred to engage a wider range of respondents to get a more diverse view of the problems in the mining sector.

The impersonal online platforms may have posed a limitation on the engagement on some of the topics. Although the researcher probed and prompted respondents to engage with key issues, there is a possibility that the lack of a physical presence could have limited this.

CHAPTER 5. RESULTS

This chapter presents the qualitative data collected from the series of one on one interviews using the semi-structured questionnaire. A description of the sample of the people interviewed can be found in Appendix VI. The results include the responses from a mixture of academics, mine environmental managers, researchers, and mining consultant. All interviewees agreed to the recording of interviews and the transcription of the audio files were performed after interviews were conducted and the documents loaded onto ATLAS.ti for data analysis. The coding of the transcripts was organized using 121 different codes and collated into eight code groups.

The number of new codes emerging were used to develop a saturation analysis (Figure 4). The new data was determined from the frequency report of codes from ATLAS.ti. The first instance of the code creation was used to generate a count and that code was then excluded from the next interview. The number of new codes where then tallied according to each interviewee and plotted, this approach was adopted from Balanco (2015).

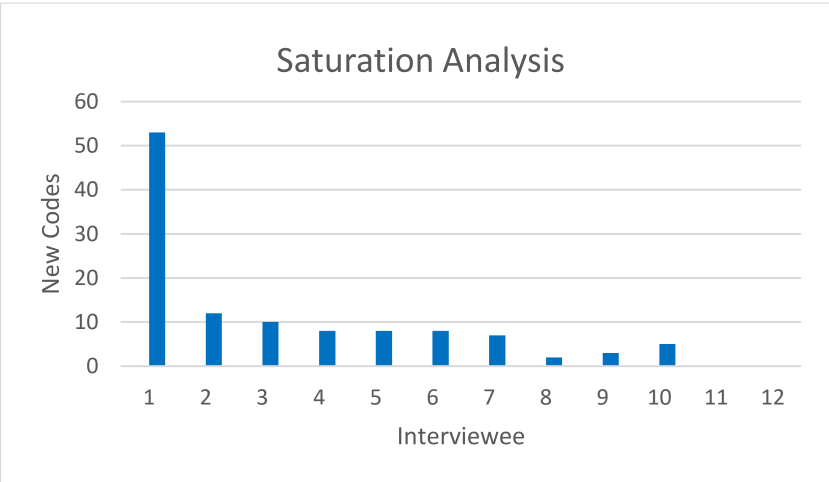

Figure 4: Saturation Analysis

The graph demonstrates that saturation was obtained by the eleventh interview, however there seemed to be an increase in codes after interview eight until ten and then a reduction to zero thereafter.

5.1 Sample Description

A series of in-depth interviews were conducted from 2 September until 10 October with individual from academia, research institutes, mining companies and consulting companies. The interviewees were organised into four categories, viz: content expert, business practitioner, consultant, and government officials. The business practitioner categories consisted of four respondents who worked at mining companies and provided critical insights on two of SA's big mining companies and one medium sized mining company. The consultant strata consisted three interviewees and were the most open and forthcoming with information and provided insights into some of the big mining houses, however they requested the names of the companies to be excluded from the report. The last group consisted of content experts from two major universities and two of SA's leading science councils. This group provided information of what the future should look like and shared research initiatives that show promise for the circular economy. A list of the interviewees is listed in Appendix VI, however, no names are included due to the promise of confidentiality and the conditions of the ethics approval.

5.2 Presentation of Results

The interview transcripts were analysed in ATLAS.ti and a word cloud developed from all 12 transcripts and presented below in Figure 5. The word cloud shows that the discussion revealed circular economy as the central and most utilised phrase in the discussion following mining and waste.

Figure 5: Word Cloud from Interview Transcript

The subsequent sections will reveal the detailed results obtained from the engaging discussions between the researcher and the respondents. The results are presented using network diagrams, graphs, word clouds, frequency tables and quotations, in combination with the researcher's interpretation. The section is structured according to the research questions presented in Chapter Three.

5.3 Introductory Clarification: What is the Circular Economy?

Prior to entering into the details of the circular economy initiatives, it was critical for the researcher to establish the interviewees understanding of the term circular economy and was therefore used as an ice breaker question but also to help the researcher structure responses and follow up questions in relation the respondents understanding to circular economy.

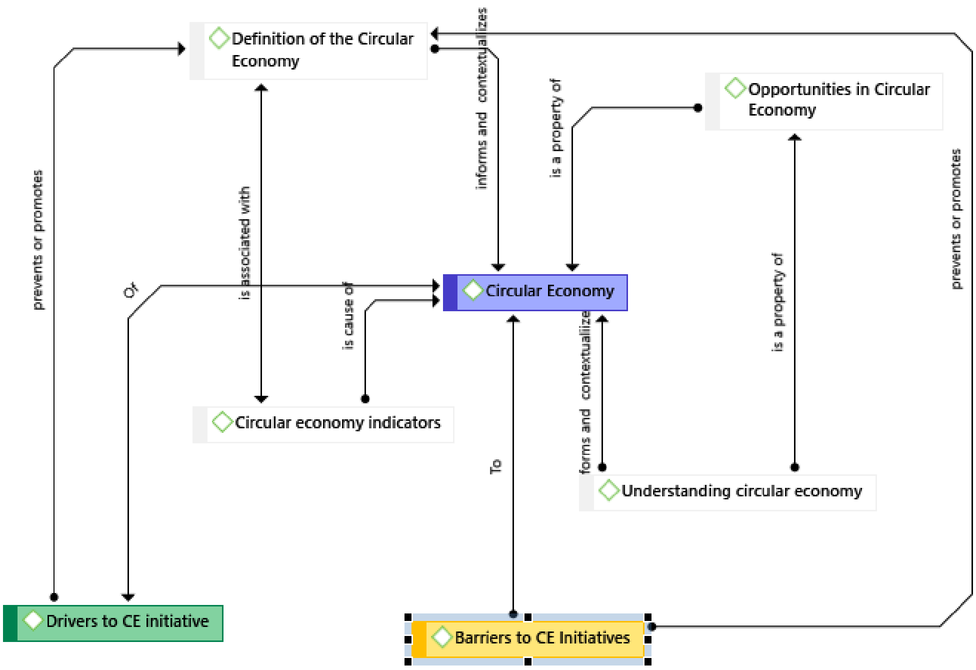

Figure 6: Network Relating to the Definition of Circular Economy

The network presented in figure 6 demonstrates the relationships of circular economy related codes, it can be observed from this diagram that the definition and the understanding of the circular economy informs and contextualises the circular economy. The frequency of the codes related to circular economy is presented in table 4. The impact of the understanding and definition of the circular economy has the possibility to both hinder and drive circular economy initiatives.

Table 4: Circular Economy related code frequency

Code	Totals	Percentage
Circular Economy	24	45%
Definition of the Circular Economy	18	34%
Understanding circular economy	6	11%
Opportunities in Circular Economy	3	6%
Circular economy indicators	2	4%
Totals	**53**	**100%**

All twelve interviewees provided their interpretations for the circular economy and although the exact descriptions varied, the core relationship was focused on waste and keeping resources in circulation. Interviewee number five explained his view as:

> "*we think about it (circular economy) in terms of ESG (Environment Sustainability & Governance) principles and their application in mining, design and operations*".

This definition relates circular economy to sustainable use and protection of the environment.

Resource reuse and the view of waste as resource was another view that found commonality amongst the respondents and this was evident in the responses of a interviewee three who said *"it's about keeping resources in flow, in the economy for as long as possible at their maximum value*", while business practitioner interviewee number 12 explained it:

> "*from an environmental perspective people look at it is how the flow of materials happen within any sector. So, it is what happens to the waste of one process. And typically, when they say circular economy, they expect that the waste of one process becomes the input or the feed to another process. So, it is looking at it from a cradle to cradle perspective, rather than a cradle to grave".*

One interview drew an analogy to nature that relates to the biomimicry nature of the circular economy:

> *"I usually think about circular economy in analogy, to nature, and to the concept of ecosystem and how everything can be integrated in chains, where something feeds something else that feeds something else"*.

The relationship between circular economy and the 3 R's, viz: reduce, re-use and recycle was also evident from the data. Interviewee two's description below as aligns with the 3 R's framework.

"trying to drive is this whole concept of regeneration. And what we understand from a regeneration perspective is that you need to develop a recyclable resource of makeover for materials and energy that you can continue to reuse without having to extract new minerals"

The central theme regarding the definition of the circular economy relates directly to the view of waste as resource and keeping this resource in circulation by beneficiation and value addition.

5.4 Research Question One

What is the status of the Circular Economy transition in SA's mining industry?

The mining sector is an extractive industry and therefore very entrenched in linear economic principals. To understand the different initiatives that exist within the mining sector, the interviewees were asked several questions pertaining to circular economy initiatives in their respective sectors and any others that they are maybe aware of. These questioned followed directly from the questions that determined the respondents understanding and definition of the circular economy, and therefore provided the researcher context with regards to the initiatives and projects they discussed.

Table 5: Initiative Code Group Frequency

Code	Total Number	Percentage
Initiative	124	60,5%
Re-use	15	7,3%
Recycling	13	6,3%
Mining waste	7	3,4%
Waste streams	7	3,4%
Anglo's Green engine	4	2,0%
Circular economy indicators	4	2,0%
Impact Catalyst	4	2,0%
Urban mining	4	2,0%
Material Flow Analysis	3	1,5%
Mine closure and future land use	3	1,5%
Tailing storage facilities	3	1,5%
Geothermal to produce methanol	2	1,0%
Sewage sludge	2	1,0%
Wastewater treatment	2	1,0%
Blue Solar	1	0,5%
Eco-friendly package design	1	0,5%
Mineral beneficiation	1	0,5%
Replacement	1	0,5%
Slag treatment	1	0,5%

Using underground water	1	0,5%
Value extraction	1	0,5%
Waste RD&I	1	0,5%
Totals	205	100,0%

All responses were coded as initiatives and the individual initiatives mentioned and any comments related to circular economy related projects were coded and collectively allocated to an initiative code group. The frequency of the related codes is presented in table 5 above.

Most of the interviewees explained circular economy related initiatives as waste recycling and re-use. Waste beneficiation activities using waste materials ranging from waste rock to used gumboots were discussed. The content experts referred to some initiatives that are still at R&D stage, an example was shared by respondent 6:

> *"Urban mining (e.g. e-waste, construction waste), slag treatment and re-use in e.g. road construction, tailings retreatment, development of water and energy and water efficient processes with minimum waste production".*

This interviewee is a career scientist at Mintek and interprets the circular economy purely as a concept related to waste recovery and re-use. She further elaborated on projects related to the re-use of acid mine drainage from mines that can be partially treated and re-used for irrigation. The Anglo American's Green Engine concept was introduced by this respondent using the following quotation: "*Examples of larger projects include Anglo's Green engine and Impact Catalyst."* These initiatives were further raised as examples of industry wide initiatives by interviewees four and ten. Respondent 6 explained the Green Engine as:

> "*Examples of larger projects include Anglo's Green engine and Impact Catalyst. However, these are also slow to take of".*

Figure 7 below demonstrates the quotations linked to the Green Engine code

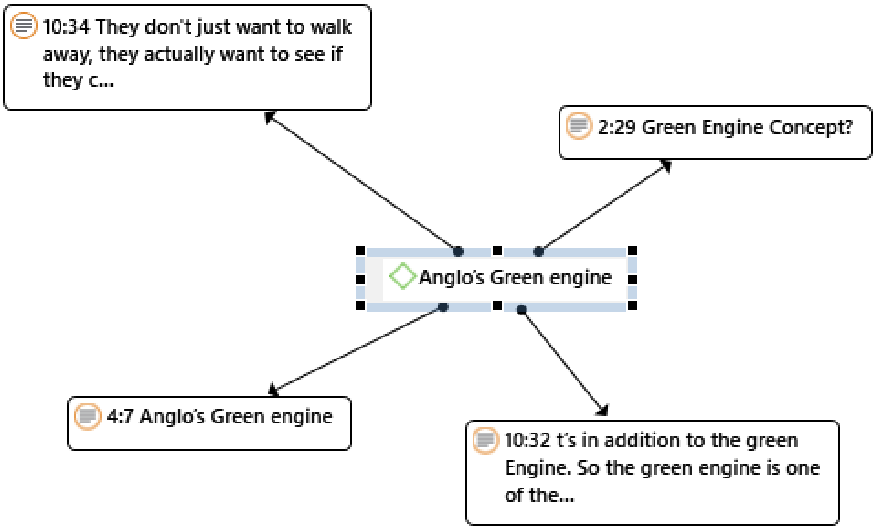

Figure 7: Network diagram of Anglo Green Engine code

The Impact Catalyst is another industry level initiative that was also initiated Anglo-American Platinum in partnership with the CSIR.

> *"it's around the Platinum mining sector, where they were looking at, you know, creating new economic activity, so that they can move labour into new jobs. Allowing them to mechanise so they can extend a life of mine. It started off with Anglo, but it includes Exxaro, Sibanye is involved as well as the Limpopo provincial government, etc.".*

Although the researcher is aware of the impact catalyst initiative it was clear from the interviews that very few of the respondents were aware of this industry coordinated initiative.

Another content expert explained, and interesting project funded by the Department of Science and innovation:

> *"one of the grant projects we're currently funding under the waste road map is Material Flow Analysis, which is being done by the University of Cape Town in partnership with Boku in Austria, which is essentially to map the level of circularity of the South African economy. And there, they are looking at all the potential flows within the South African economy, which would include both primary and secondary resources"*.

Interviewee eight is the lead on this project and explained that the project will provide a set of indicators for circularity of resources in SA that will "*get all significant flows of materials mapped for South Africa "*

Environmental mangers that were categorised as business practitioners associated with three different mines in SA. A word cloud was created from the business practitioner respondents transcripts (Figure 8), Interestingly the most used words amongst these interviewees were water, mining, and waste, then circular economy, while the expert and government official conversations were dominated by the use of economy followed by circular, mining and then waste.

Figure 8: Word cloud of Business Practitioner group

Interviewee four described a few initiatives that are currently active at the Anglo American mine, and described one as:

> *"setting up now is we looking to separate waste, into recyclables at our operation, and setting up a company within the community to remove this waste, and actually extract value from it"*.

The mine generates over 1.5 tons of waste rubber from gumboots and conveyor belts per annum, that is sent to a company and they *"put the gumboot through a shredder machine, high level shredder machine, and then sells that product, you know, to the next person"* as a raw material for their product.

Other mine level initiatives were described by interviewee four was about the reuse of underground process water for above ground processes like dust suppression and washing of vehicles, coal etc. He explained that:

> "*about five years back we've converted to using process water and that process water is actually water that we pump from the underground*

sections. We settle the sediment in dams and then pump it back underground. CMs use it, we use it for dust suppression. So, your CM is usually water sprayers. It is just to mitigate you know dust from the cutting operation so one may get used there. Another to make weed pump through to the Paula Processing plant and that's to wash coal".

These initiatives are using water that was otherwise destined to be discharged into various waste streams with the potential to contaminate ground and other fresh water sources. Interviewee 11 highlighted similar initiative at the Mbuyelo mine.

Interviewee twelve explained the initiatives that are using tailing storage facilities as a source to recover gold:

"So, what we doing now with the companies that there's been a lot of reprocessing of that material, and mainly to still get more of the gold that is still locked in those attending storage facilities."

In the past the processing of these dumps for gold recovery was not feasible, but with new technology this process has become economically achievable and has therefore become a business strategy for some mines as observed in this quote:

"AGA started realizing that there is a business case for reprocessing of this alternative storage facilities, they then there was a business strategy to say you know what, because we don't have to dig the ground again to go and access the gold which is also very expensive because depth of your mine, it will take you about three to four years just to get to the seam because you need to blast almost every day"

and the mines are implementing various initiatives that are aimed of getting value from waste streams and recycling were possible.

The consultant group of respondents described remarkably similar initiatives to the business practitioner, respondent two and five highlighted integrated projects that seems to fit perfectly with the circular economy definition.

"minerals beneficiation project. And the idea is to beneficiate low grade ore, and the process can work for iron ore, manganese, or chrome beneficiation, that using a carbon-based source, and that could either be coal per se, or it could be municipal waste. And the idea would be that you quarantine the off gas, you pass the off gas across a bit of algae, and algae then absorb the off gas as part of photosynthesis. We also then use municipal wastewater and feed that to the algae. They absorb the

nutrients from that, and then basically produce water, hydrogen, and oxygen".

The project as described in the quotation from interviewee five presents an integrated approach waste re-use, material upgrading and keeping materials within the economy for as long as possible.

The initiatives mentioned by majority the respondents were described as on track, however this needed to be qualified based on the type of initiative. The R&D concepts on acid mine drainage are on track from the perspective of the process development Gantt charts but is not yet commercially implemented. The analysis of material flows was also explained to be on track; however, this initiative will provide information to establish material flows and not an initiative that will add direct economic impact from the circularity.

Initiative described by the business practitioner groups were already implemented and realising benefits to the triple bottom line. Examples of these are the recycling of rubber from conveyor belts and gumboots.

> *"it's an input into another process. And yeah, we get in it. So, I mean, we get R1,50 for each boot, which we would normally be dumping on in our domestic waste".*

The initiatives around tailing dumps processing for gold is an active initiative and has become part of business strategy of big mining companies, "*I think for DRD Gold, it's basically their key business strategy*".

5.5 Research Question Two

What is hindering and/or driving a Circular Economy transition for SA's mining sector?

The discussions with the interviewees raised several issues that were interpreted as barriers or drivers to a transition to circular economy business models for the mining sector. These hinderances and drivers are reported here under the respective sections.

5.5.1 Barriers

Barriers were identified as anything that is currently or has the potential to prevent the implementation of circular economy initiatives. The code frequency table for hinderances presented below (Table 6) demonstrate that regulations was cited as the largest barrier to the circular economy.

Table 6: Hinderance Group Code Frequencies

Codes	Total Number	Percentage
Regulations	35	25,0%
Government	26	18,6%
Funding	12	8,6%
Not core business	12	8,6%
Available skill	10	7,1%
Partnership	8	5,7%
Understanding circular economy	8	5,7%
Funding initiatives to assist circular economy transitions	5	3,6%
Available technology	3	2,1%
Available mineral deposit	2	1,4%
Awareness	2	1,4%
Enforcement	2	1,4%
Human waste	2	1,4%
Authority	1	0,7%
Big mining firms	1	0,7%
Competitiveness	1	0,7%
Incentives	1	0,7%
Market incentives	1	0,7%
Nature of industry	1	0,7%
Pressure	1	0,7%
Required material	1	0,7%
Risk	1	0,7%
Skills development programs	1	0,7%
Technology maturity and complexity	1	0,7%
Threat on employment	1	0,7%
Threat to mining industry	1	0,7%
Totals	140	100,00%

Government was suggested as the next largest contributing barrier, however the government and regulations coded are related as visible in the network diagram for the hinderance code in figure 8. Consultant interviewee number five seem to think that

> *"less government regulation not more is needed; the industry is overregulated as is"*,

this was contradicted by content expert from Mintek when she said, "*lacking policies that support a circular economy transition"* as well the *"lack of enforcement of the regulations"* that do exist.

The content expert from the CSIR shared her preference for the circular economy to be "*driven out of the Department of Trade industry and competition, because it's an* *economic driver”.* She also expressed concern:

> *“because everything that you see about the circular economy, and even you know, the infamous butterfly diagram, the mining sector kind of always sits outside of the butterfly diagram”*

coupled with the fact that

> “*there are some people that see the circular economy as a threat to the mining industry, where it's a case of well saying, okay, so we don't need these primary resources anymore. So, you know, what does this mean for the mining industry”*.

She further clarified this by referencing a Dutch study that suggests the *“SA stands to lose roughly 3% of GDP if the EU moves to fully circular economy”*

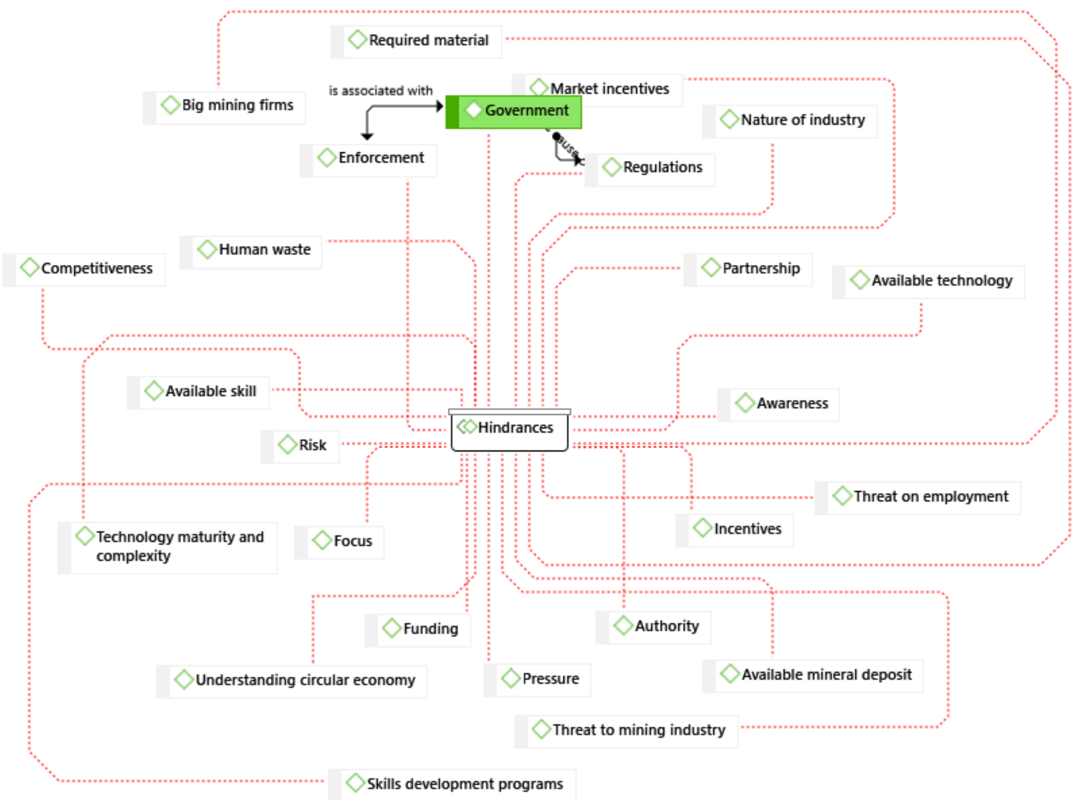

Figure 9:Network diagram for Hindrance code group”

The lack of policy was highlighted by interviewee three when she referred to the fact that

> *“we only have two policy documents that specifically referenced the term circular economy, and that is the new white paper on science, technology and innovation and that will be taken forward into the DSI as new decadal plan”.*

This highlights the regulatory impetus is lacking specifically around the circular economy.

The democratic government and "*how easy it is to change a governance program every four or five years*" was also sighted as barrier due to fact that each change in leadership ushers in a difference view on how policy should be drawn out thereby impacting the mines progress toward a circular economy. Interviewee 11 presented a regulatory hurdle that was similar to this when he explained that:

> *"government is complicated, because you might have international I mean, national department, which is supposed to authorize, and you also have your local government, and your district government, which has other bylaws"*.

This view was also shared by interviewee one who voiced a concern about *"what happens every time the government tries to enforce something"*. This statement was drawing reference to the civil disobedience and protests that arise when government try to police some regulations.

Regulatory uncertainty emerged as another area that places barriers to circular economy initiatives, respondent two explained that they would rather establish:

> *"beneficiation operations in Botswana rather than South Africa because there's just much more regulatory certainty within Botswana. We just need certainty, just tell us what they want us to do and support us, then we do that. So, if they say a policy is in place, we want to be able to end with piece of legislation we are able to rely on that in actually driving the businesses and the processes going forward".*

After regulations and government, funding was highlighted as the most recurring code. Respondents expressed their concerns about the lack of funding for initiatives that are circular in nature or aim to transition to a circular economy principal. The business development manager from a consulting company explained "*there is some appetite for some of it, you know, trying to get it funded is really hard".* Interviewee two concurred with a statement:

> *"tailings reclamation opportunities are perceived by smaller companies and start-ups. And those are the guys that typically struggled to get financing for these opportunities"*

The funding barrier was linked to risks that was highlighted by respondent nine when he said,

> *“innovation at the beginning requires an investment that has a cost. And that you know, construction industry does not like risks. And I think mining industry does not like risks as well. And those are intimately linked to the inability to investigate opportunities to think on a long term. And circular economy requires thinking on long term”.*

From table 6 we can see that the code on “not core business “emerged as the fourth most prevalent from the discussions. This implied that several of the respondents did think that circular economic principals are not core to the business of mining companies. This was justified by comments made by a consultant who explained

> “*current mining sector is not focus on the circular economy whatsoever, because it's an extractive industry. They mined material and they export material, and they have to do some social investment, but that is only focused on ensuring their present operations can be sustained whilst they're in operation”*

This statement clearly demonstrates that circular economy is viewed as something that is not in the best interest of the business and possibly why it is not mainstream in mining companies and therefore the time, effort and funding required for related initiatives are not always given the approval because of this.

In line with the theme of circular economy not being core business, this implies that CEO’s will focus on what is best to deliver value to their shareholders and therefore steer clear of long-term initiatives like circular economy because:

> *“there is a lot the mining industry can do. But they need to have a 20-year vision. And for a CEO that is appointed for a five-year period to optimize value for shareholders, that's not necessarily the outcome that they're driving”*,

explained by interviewee two. He further explained that it easier for a mining company to start a new mine to secure supply than to explore circularity of resources to fill the void. The content expert from UCT also share these sentiments when he states: *“that’s not their business model”*. Interviewee nine and ten both concurred that transitioning mining companies to a circular business model is not core to their business and will therefore always be a secondary initiative.

Partnerships also emerged as a contributing barrier to the circular economy and cited by respondents one, four, seven, ten and twelve. The general theme was that there is a need for collaboration across the industry for circular economy initiatives to work, however due competition within the industry and lack of coordination this is not happening. Initiatives like the Impact Catalyst could generate the required industry wide collaborations to enable the circular economy transition, unfortunately only one of the twelve respondents were aware of this initiative.

Respondents did not all seem to agree the availability of skills as a barrier to circular economy transitions with 67% believing that SA does not have the skills. Respondent eight who is an academic from UCT stated:

> *"we are getting more youngsters trained in engineering into the economy, but we are still relative to the advanced economies. Our ratio of engineers 200,000 people is ridiculously low",*

this statement suggests that although we are making progress regarding filling our skills gap, we still have some ground to cover to reach the developed nations.

5.5.2 Drivers

The codes that were associated with the code group related to drivers of the circular economy are listed in table 6 below.

Table 7:Code Frequency for Drivers code group

Codes	Total Number	Percentage
Regulations	35	28,9%
Drivers to circular economy initiative	25	20,7%
Waste beneficiation	19	15,7%
Cost saving	14	11,6%
Economic growth	13	10,7%
Economic factor	6	5,0%
Value creation	5	4,1%
Market	1	0,8%
Relationship	1	0,8%
Security and scarcity	1	0,8%
Security of supply	1	0,8%
Totals	121	100,0%

The discussions with all those interviewed revealed that it was easier for respondents to identify barriers than it was to identify items that support the circular economy transitions. Although regulations were also viewed as an enabler to the circular economy transition, this view was only supported by a few of the respondents. Respondent three viewed the National Waste Management Act as a strong driver of the circular economy, however believed that the implementation and enforcement was lacking. A consultant to the mining sector (interviewee 5) explained.

> *"there's now a policy which says, we need to change our energy mix. So, you know I think there is pressure to change",*

this policy will be a true enabler to circular economy, however only if the generation of the energy is through waste materials and promotes material flows.

Interviewee twelve believed the MRDPA forces mining companies to innovate around waste recycling:

> *"Mineral and Petroleum Resource Development Act (MRDPA), regulations, those are quite good as well and are key legislation to drive circular economy in mining by as they are the ones that are for this kind of circular economy, because they force us to identify those projects, and then ensure that we also don't only implement it at the mine level as well as at the community level as well".*

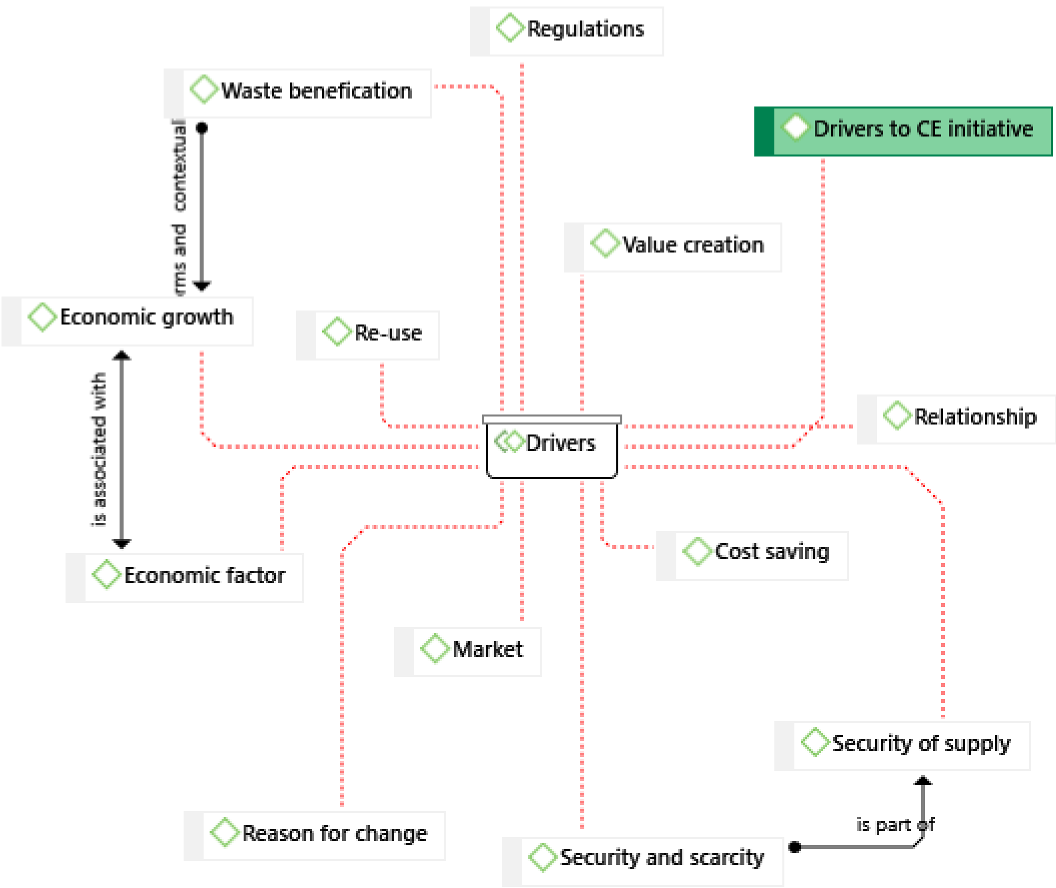

Figure 10: Drivers of the Circular Economy Network diagram

South Africa is not known for its rare earth resources, however one of the content experts indicated that this scarcity of resource could drive CE:

> *"If you want to access rare earths, you know, you can do it pretty cheaply out of electronic waste without having to go and kind of three kilometres below ground and if mining houses see the circular economy as an opportunity to top up what they're extracting out of the ground, then*

absolutely"

Figure 10 above demonstrates the network of codes found from the discussions with the respondents and highlights scarcity of supply as a driver of change. The global view on climate change is also pushing for circularity and therefore interviewee five said:

> "*stakeholders' pressure around climate change, pressure from host communities, pressure from regulators, changes in legislation – social license to operate consideration"*

Mining companies are in the business of making money and any initiative that is not going to generate and income is either not going to start or is one that is in response to an enforcement of some regulation. However, with the circular economy there is potential to generate economic value as explained by respondent three:

> *"if government is not going to be the one to implement the circular economy, it will be business and, business will do it because it makes good economic sense".*

This view was supported by content expert who stated, "*there has to be an economic imperative first"* and that will drive the transition to circular economy.

5.6 Research Question Three

Based on the MLP and sustainability transitions theory, what needs to change to accelerate the Circular Economy transition?

The mining sector is a key economic driver for the SA economy, and it employs a significant amount of the population and therefore its sustainability is import to all South Africans. The barriers identified in the preceding section provided some interesting areas that can be addressed to promote a circular economy. However, the strata of people interviewed revealed thought-provoking perspectives on what they believed should be changed to aid a successful transition to a circular economy in the mining sector.

The coding of the conversation related to the changes that are needed to move to a circular economy returned several codes and the frequency of these codes are listed in table 7 below. Some of the codes are shared with other themes, including that of regulations. Regulations was cited as barrier and driver and was also highlighted as one of the critical items that requires change.

The group of Business Practitioners suggestions on what requires change in relation to regulations were dominated by requests for changes in certain legislatory frameworks as well as proposing incentives for the treatment of waste materials. Respondent nine thought that the policies must change to reflect *"incentives and stability"*. Interviewee 11 believed that the MPRDA should be changed to be the guiding policy document for the circular economy in mining. He also felt that these should be at the Macro or Landscape level:

> *"centralise such policies and have one specific policy, which can touch on several paths, but managed by one department",*

which will make compliance easier and provide clear guidelines on circular economy initiatives. Most of the suggestions from this group were targeted at making regulations more enabling and easier to implement at the mine level.

Table 8: Code Frequency for the Theme of Changes Needed

Codes	Totals	Percentage
Regulations	35	26,12%
Micro level- Mine level	19	14,18%
Focus	12	8,96%
Funding	12	8,96%
Macro level - County Level	11	8,21%
Meso level/ industry level	11	8,21%
Partnership	8	5,97%
Awareness	3	2,24%
Change business model	3	2,24%
Opportunities in Circular Economy	3	2,24%
Training	3	2,24%
Implementation	2	1,49%
Innovation	2	1,49%
Reducing mining	2	1,49%
Sectorial Integration	2	1,49%
Targeting the correct audience	2	1,49%
Custodians	1	0,75%
Employing expert	1	0,75%
Quality	1	0,75%
Waste finding	1	0,75%
Totals	134	100,00%

The relationships between the changes required and the multiple codes are presented in the network diagram presented in figure 11 below. The diagram demonstrates the various linkages between codes and how they have the potential to make positive impacts.

The understanding of the circular economy was highlighted as a barrier, however, its link to opportunities in circular economy demonstrate that improved understanding of the circular economy will generate opportunities.

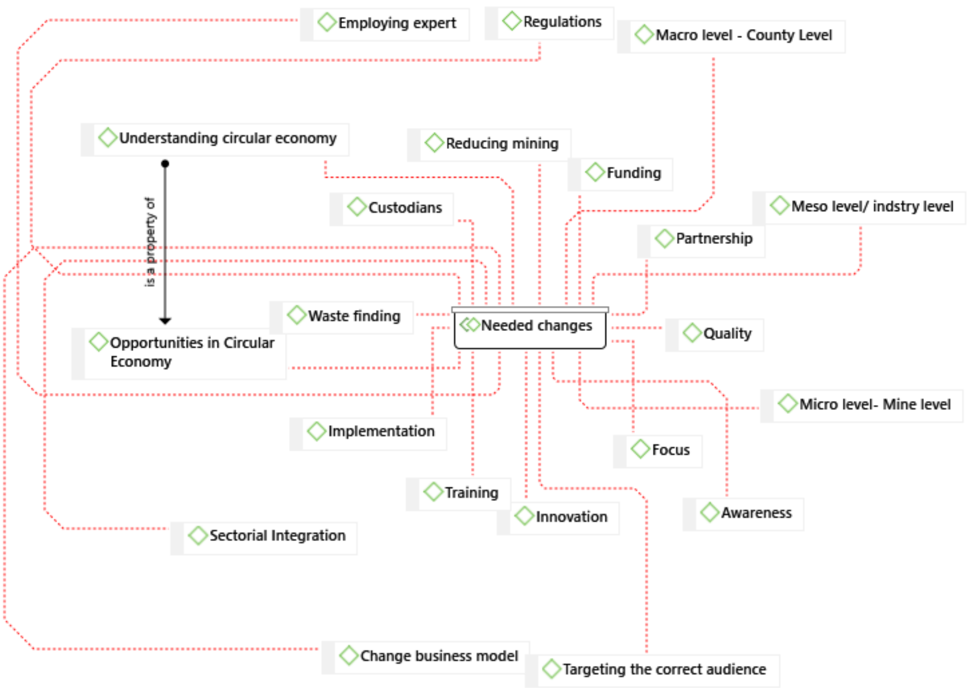

Figure 11: Required Changes for circular economy Transitions Network Diagram.

The consult group of respondents presented similar suggestions on regulatory changes that remained with the government *"facilitating and simplifying process".* The mining charter and the policy uncertainty around mining needs to be addressed in new regulations to providing a guiding philosophy to transition from and extractive to a circular economy.

The content experts and the government official seemed to agree on the development and implementation on specific circular economy related policy rather than amendment and facilitation of existing mining legislation to enable the transition, like the other two groups.

The codes related to changes required at the micro or niche level was described by content expert from CSIR related to a change in business model and one that focuses on implementing circularity plans to access resources from waste rather than extracting new material. However, interviewee 5, a consultant, highlighted that this depended on whether *“markets and effective demand for waste management products or processes do exist”*

to support these initiatives. The content expert from Mintek made an interesting suggestion for mines stating that:

“The first step is to look at their portfolios to assess where the risks of decreased demand or substitution loom largest, determine which materials can be recovered more effectively, identify where circular business models present opportunities”.

She also suggested that mines need to innovate with circular products and services in mind to make changes hold. Respondent one presented his view that at the *“mine level, you need to be able to target the correct audiences”*, he further stated that this would mean pitching to international audiences as the *“right audience”* seldom sit in SA.

Designing a green field mining project built on circular economy principles and demonstrate the impact, this will provide data-based evidence to support the circular economy and will making convincing decision makers a lot easier. This view expressed by respondent two was shared by content expert professor from UCT but he added that mining companies *“really need to look at the providing access to capital”* for circular economy projects.

Environmental manager, interviewee eleven said:

“*to empower your team by training them and developing them. Because in most instances, you find that the key decision makers are not really clued up when it comes to business or environmental or reuse of resources. So, you a get a person who is acting on the role of a CEO, but he is not fully trained or fully aware of, the activity related concerns, or programs. So, I think our awareness training should be the first”*.

This statement suggests that circular economy should be a critical part of training schedules for mine employees and the implications of this lack of circular economy awareness escalates through the length and breadth of the mining companies. Business practitioner twelve agreed with this view and suggested a further intervention that will help foster a circular economy will be to include circularity targets for mines. These targets and metrics must be implemented as key performance indicators of key personal in the organisation, including the CEO. A further suggestion around the leadership of mines was that mining company CEO are employed for five to ten-year terms and for circular economy initiatives to make real impact requires a longer-term view. CEO's therefore do not consider these types of initiatives as they will not see the reward within their tenure. A mechanism must be implemented to circumvent this barrier.

The meso or industry level code was based on questions to determine what needs to change at the industry or regime level to aid the circular economy transition. There was a view that an industry wide *"workshop and a couple of studies to be done, on whether the circular economy is a threat or an opportunity"*, Anglo American have conducted studies like this however a collaborative approach to identifying the opportunity and demystifying circular economy will aid this transition through knowledge. Respondents one, two, three, five and six suggested that an industry level business model shift needs to occur to enable the circular economy transition, because the current regime is too focused on financial returns to see the value of circular economy.

> *"Environment Sustainability and Governance (ESG) platform, that's the language the industry understands, and you need to fit the circular economy into the ESG paradigm to make it relevant to the industry".*

This point is important as it suggests using existing regimes to drive the circular economy transition.

> *"This approach could drive an industry wide drafting of a circular-economy strategy. Build strong business cases for the initiatives proposed in the strategy. Devise a plan for implementing these projects, including strengthening needed new capabilities".*

This was the view of content expert from Mintek and she was extremely passionate about the implementation of circular economy technologies and projects in the mining sector.

Several the respondents raised the Minerals Council as a body that should be leading this transition because of its cross-cutting influence in the mining sector. The minerals council can coordinate the

> *"mining companies to band together around carbon credits. They already own a non-carbon tech issue with carbon credits. So, you start trading in carbon credits. So, if you are a big industry, you look at this mining industry, very raging much more carbon dioxide, look at how you can trade credits with them, for example"*.

Unfortunately, none of the people approached from the Minerals council responded to request for interviews.

Majority of the suggestion around the landscape or macro level interventions to aid the circular economy transition was focused on regulations and policy certainty, which was presented earlier when discussing regulations.

5.7 Conclusion

The results obtained from the twelve interviews presented a wide range of different viewpoints and raised several pertinent questions with regards to the mining sector. Respondents were asked questions to probe their thinking around the three levels of society to establish a framework for data presentation in line with the MLP framework. The responses received during interviews were sometimes shared but often contradicted, suggesting that the area of circular economy theory is still very much in its infancy in the mining sector and the understanding of what circular economy is very diverse and sometime divergent.

The data highlighted the various initiatives that are currently being implemented at various mines and the initiatives that are still at the R&D phases. The discussions also revealed that although there are numerous barriers to a transition to a circular economy in mining, there are some drivers that could streamline the transition. Chapter six will discuss these results in comparison the literature study presented in Chapter two.

CHAPTER 6. DISCUSSION OF THE RESULTS

In this chapter, the results as reported in Chapter 5 are interpreted and discussed in relation to the previous studies reported in the literature review in Chapter 2 and the conceptual framework of the MLP. The chapter is structured according to the research questions. The chapter presents the initiatives and their status in relation to other studies and aims to determine the conclusive findings on what is driving or hindering the transition to a circular economy. The interpretation of the respondents' views on what needs to be changed has been discussed using the framework of the MLP. Necessary changes to the circular economy business model at the niche, regime and landscape levels have also been identified.

6.1 Respondents Understanding of Circular Economy

As part of the introduction during each interview a question on the respondent's interpretation was asked. This question was to determine the respondents understanding of what circular economy is about. The study found that the definitions provided by the participants could be clustered into two groups viz: extending material flows, and regeneration and recycling. The broad definitions from these groups could be restated as depicted in table below.

Table 9: Clustered definitions of CE

Group	Definition	Participant Group
Extending material flows	CE is related to keeping resources in the flow within the economy for as long as possible	Content Experts and Government Official
Regeneration and Recycling	CE is about taking a cradle to cradle approach to waste use, were the waste from one process is the raw material for another	Consultants and Business Practitioners

The definitions although similar highlight two different perspectives. The content experts were extremely forthright about not linking the term waste with the circular economy, their view was that the wastes are resources waiting for a use to be innovated. Their view was that the flow of resources must be maintained within economy for as long as possible. This definition concurs with the definitions provided by the Ellen MacArthur foundation that state: *"A circular economy is one that is* *restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times*" (Geisendorf & Pietrulla, 2018). This definition demarcates the direct relationship between waste and circular economy. Although the use of waste as a resource is inferred in the definition, the definition is broad enough to expand the "waste resources" to include waste time and opportunity. This definition is what aligns to the new age sharing platforms like Uber and Airbnb (Lewandowski, 2016).

The relationship of circular economy and waste management was presented by the environmental managers that were assigned to the business practitioner group. This definition looks at the circular economy as the regeneration and recycling of waste. This definition is correct but does provide some limitations in that it still limits its scope to waste management. Based on the study conducted by Geisendorf and Pietrulla (2018), the dominant view of circular economy aligns best with the Ellen MacArthur Foundations definition.

6.2 Status of The Circular Economy

The MLP framework specifies two important preconditions for transition, namely radical landscape pressure that destabilises the socio-technical regimes and at the micro level, the emergence of strong niche players who collectively present a real threat to the status quo, within the socio-technical regimes (Schot & Geels, 2008). The subsequent data for this section will be discussed in relation to this theory.

This section relates to one of the three leading research questions of the study and was designed to obtain an understanding of what circular economy initiatives are currently in place in the mining sector. The results from the four groups of participants demonstrate that there are currently a few active and successful circular economy initiatives that are implemented at the mine level.

Table 10 presents a consolidated view of initiatives mentioned by interviewees and their corresponding status and literature reference to similar initiatives. The results revealed nine different initiatives discussed by participants, majority of which were mentioned by more than one interviewee. The various initiatives have found reference in prior literature and link to publications are listed in the table 9 with the status of the projects.

Table 10: Circular Economy Related Initiatives in Mining

Project	Description	Interviewee	Group	Literature	Status
Material flow analysis	The project maps the flows of various materials within SA and to assess the level of circularity in SA	3 and 8	Content Expert	(Lieder & Rashid, 2016)	R&D project
Secondary Platinum recovery	Recovery of Platinum from Catalytic converters	3	Content Expert	(Rumpold & Antrekowitsch, 2012; Saidani et al., 2019)	Commercially implemented
Rubber recycling	Recycling of gumboots and conveyer belts	4 and 12	Business Practitioner	(Toteva & Stanulov, 2020)	SMME initiative implemented
Underground water Reuse	Reuse of water that was underground for above ground activities like washing truck etc.	4 and 11	Business Practitioner	(Lin et al., 2020)	Initiative Active at mine
Urban Mining	Urban mining (e.g. e-waste, construction waste), slag treatment and re-use in e.g. road construction, tailings retreatment, development of water and energy and water efficient processes with minimum waste production	6	Content Expert	(Kinnunen & Kaksonen, 2019; Zeng et al., 2018)	R&D project
Green Engine	Integration of various waste treatment processes to move toward zero waste	6 and 10	Content Expert	(*World Water Week 2019 - Water for Society: Including All | Anglo American*, n.d.)	Pilot Project
Impact Catalyst	Stimulation of economic activity around mines	6 and 10	Content Expert	(*Impact Catalyst*, n.d.)	Pilot Project
Coal Discard Project	Production of Biomethane from Coal discards	1	Consultant	(Zhang et al., 2016)	R&D project
Tailing Reclamation	Reprocessing tailing dumps for minerals	6 and 12	Business Practitioner	(Kinnunen & Kaksonen, 2019)	Pilot and Planned

Material flow analysis was an initiative mentioned by two of the content experts and described as an initiative the maps and determines the flows of materials within the South African system. This project is at the research and development stage; however, it does provide critical information regard circularity of materials and will provide areas of potentially new circular economy initiatives. Similar studies conducted in China proved valuable in identifying areas where circular economy initiatives could be implemented and also helped inform policy (Lieder & Rashid, 2016). In another study conducted by Saidani, Kendal, Yannou, Leroy and Cluzel (2019), MFA was used quantify and reduce obstacles to transitioning to a circular economy, and also promoted an circular economy initiative to recover platinum from catalytic converters.

Secondary Platinum recovery was a circular economy project cited by the content expert from the CSIR. Unfortunately, the participant was unable to provide live examples of its implementation in SA and therefore the project was considered R&D. The project did find its basis in literature from the study by Saidani, Kendall, Yannou, Leroy, Cluzeet, (2019) an a scan of the literature revealed similar programs are indeed active in SA. A company called Valsotrim Pty Ltd. (www.vaslotrim.co.za) has built a business model around the recycling of catalytic convertors to supplement the Platinum and Palladium supply chains and employ a hydrometallurgical process (Rumpold & Antrekowitsch, 2012) to extract and recycle the precious minerals from the waste.

The mining sector is synonymous with the usage of rubber because of conveyor belts, gum boots and tyres employed in the industry, and have developed a reputation of being one of the largest generators of rubber waste (Toteva & Stanulov, 2020). Respondents four and twelve mentioned similar initiatives employed at the niche level. These rubber recycling programs are empowering the communities and returning a value of R1.50 per gum boot. This demonstrates a typical example of value generation in the circular economy as the waste generator now has reduced or removed the waste and have made it a resource for another business and at same time providing a financial return as opposed to an expense associated with waste rubber.

The rubber recycled at the mines are sold to companies that employ pyrolysis technology to produce oil for the fuel industry or used in concrete manufacture (Bignozzi & Sandrolini, 2006; Toteva & Stanulov, 2020). This initiative provides a holistic response to waste management using the circularity of rubber a case study. Rubber is non-biodegradable and if left untreated will leach toxic chemicals into the environment (Chung & Hong, 2009). It will cost mines significant amount of money to remove the waste but also create negative public perception. This initiate has been able to address all these areas and realise a positive outcome like Kabusha OTR who has built a business model around recycling waste rubber from mines (Breytenbach, 2016).

Water issues in the mining sector are often associated with acid mine drainage, however the immense wastage associated with underground water use is often overlooked. The re-use of this water provides an opportunity to reduce the mines water footprint drastically. An Anglo-American Coal mine in Emalahleni is actively recycling its underground process water for above ground processes. The water is pumped to the surface and used for washing mine trucks and plant as well used in an adjacent coal washing facility, that provides a service to multiple mines in the area. Although situated at the niche level, the initiative is a regime level intervention that provides an industry wide water saving and environmental benefit.

Similar initiatives implemented at the regime level have been discussed such as the use of process water for floatation and other activities (Lin et al., 2020). The researchers demonstrated how the project delivers value to the triple bottom line by reducing costs associated with water use and contaminated water disposal, the positive environmental impact of reduced water use and discharge of contaminated water and the impact on the positive perceptionof staff and neighbouring communities on the reuse of waste water. A study on the circular economy in the metals sector demonstrated that the negative environmental impact of not reusing waste and process water is significantly resulting in eutrophication of rivers and dams, contamination of ground water and destruction of aquatic life (Abubakar, 2018).

Anglo-American Platinum mining division is committed to transitioning their trucks to a greener fleet by replacing diesel mine trucks with hydrogen powered ones. This initiative was mentioned by respondent five, as a micro level initiative. This initiative is extremely important to the mining sector as a driver to become greener, however the initiative lacks circularity, unless the hydrogen is generated from mine wastewater. This is currently unclear, and the initiative was therefore excluded from current circular economy projects in the mining sector (Njini, 2020).

Urban mining was reported by one of the content experts and considered this as a critical initiative for the mining sector to mitigate the longer-term risks associated with diminishing resources. Urban is a program that can be implemented at the regime level and supported by landscape level regulatory support. Urban mining is far more cost effective than virgin mining and the levels of resources available in electronic waste is high enough to make economic sense (Zeng et al., 2018). A study on circular economy benefits and bottlenecks contradicted the view of Zeng et. al., that e-waste provides a cheaper source of materials than virgin sources (Kinnunen & Kaksonen, 2019). Both studies did agree that urban mining is a circular initiative that can enhance value to beyond the sum of its parts. This initiative has not gained momentum within SA due to the lack of technology to efficiently and cost effectively extract minerals from the electronica waste. Content Expert 6 explained that there are R&D initiatives to develop hydrometallurgical processes at Mintek that do demonstrate promise and could make this circular economy project a commercial reality in the next year or two.

Regime level circular economy projects suggested by the respondents were limited and this highlighted a lack of coordination across the industry. The initiatives that were mentioned were the Algo Green Engine and Impact Catalyst projects. The Anglo Green engine project was mentioned by three of the respondents, however other respondents were not aware of these projects. The green engine project can be considered an adaptation of an earlier initiative spear headed by the CSIR that integrate waste from various processes to generate circularity within communities. The Green Engine appears to have adopted some of these circularity concepts. The project has the potential to make significant impacts in the transition of the industry, to a circular business model. However, with the lack of awareness of the project, the likelihood of its success is extremely limited. It also appears to lack the required skills to translate it into a reality.

The Impact catalyst is another concept that has potential to help the transition at the industry level. This project was only mentioned by one respondent and none of the other respondents knew about it. The Impact Catalyst is a concept that looks at creating new economic activity around Platinum mines in Limpopo and has key mining companies in collaboration. These companies included Algo Platinum, Exarro, Limpopo Provisional government and others and is driven by the CSIR. A surprising observation was that although the CSIR drives the Impact Catalyst, the content expert from CSIR was unaware of the initiative.

The Green Engine and Impact Catalyst projects are the only two projects cited that have the real potential to aid the transition of the sector to a circular business model, yet the awareness is lacking and can potentially limit the impact.

The generation of biomethane from coal discards was an example of a project that utilises a waste resource to generate an alternate and cleaner form of energy. The project is currently at the R&D phase at Mintek and can help generate energy as a product for the mines, while reducing the environmental impact of coal dumps that litter the mining landscape. The concept of producing biomethane from discarded coal has been studied extensively by a group at the Southern University of Illinois (Zhang et al., 2016)

Tailings dumps are scattered across the Gauteng scenery and have created long term negative environmental impact. Respondents six and twelve believe that these tailings dumps have significant circular potential and can help move mining into circular business models. Interviewee twelve highlighted that Anglo Gold Ashanti has included the reprocessing of tailings as part of their business model and there are companies like DRD gold who are actively buying tailings facilities to drive their strategy of circularity through waste processing. Kinnunen and Kaksonen (2019) found that the recovery of metals from tailing was a huge opportunity in the sector and it was easier and quicker to start than Greenfield mining projects.

Only one intervention at the macro or landscape level emerged during the discussion which was raised by the Government official and content expert from CSIR. This related to DSI's white paper (DSI, 2019) that included Circular economy and the DSI's decadal plan. This document explains the intention to support a transition through offering financial support for R&D projects that can aid the shift a circular economy, however, there is still a lack of policy interventions that directly apply to the circular economy. During the discussions, the potential emergence of a circular economy policy driven by the Department of Environmental affairs emerged, but this could not be confirmed. The DSI's white paper does indicate that multiple departments are working together to develop a circular economy plan for SA, however it has been almost two years since the release of the white paper and no consolidated government response to the circular economy has emerged.

The MLP framework, although not processual, provided some guidelines on what activities should happen first for a successful change. For a successful transition there is a requirement for effective niche level management to push emerging technologies to support the transition (Schot & Geels, 2008).

Ideally the transition to the circular economy should result in a sustainable industry that demonstrates circularity in material flows and as a result minimal impact on the environment. Waste management processes should be designed into processes and become a core business function.

In summary, there appears to be some level of landscape pressure being applied through improved awareness of the environmental impacts of mining. Although government policy interventions and regulations are limited, they are contributing to increased pressure on the regimes. Unfortunately, these pressures are insufficient to significantly destabilise the regime. The evaluation of the responses from the interviewees have demonstrated that there is little evidence of niche management, highlighting limited leadership by government in supporting niche development and implementing the necessary regulatory reform. As a result, the transition is characterised by internal reforms within the regime, which are slow and insubstantial.

6.3 Niche Management for the Circular Economy

6.3.1 Barriers

Research question one sought to determine the circular economy initiatives in the SA mining sector as well as determine the status of these initiatives. Research question two was devised to identify the factors that drive or prevent circular economy related initiatives in the mining sector. The results obtained from the 13 interviews highlighted that there are potentially 26 differently items that can be linked as barriers to circular economy transitions. The top five codes as highlighted in Table 5 are regulation, government, funding, business models and available skills. Regulation and government can link together as the leading hurdle and will be discussed first. A masters dissertation on the circular economy (Bechtel et al., 2013) determined, from twenty seven interviews, that the barriers to implementation of circular economy processes could be clustered into four categories. These were Technological, Legal, Economic and Change in Mindset, and the top five codes reported in this study aligns to these four areas. Government and Regulations fall within Legal, Funding falls within Economic, while business models cluster into Change in Mindset and available skills can sync with Technological.

The lack of appropriate policy has been cited by all thirteen respondents as a major barrier to any attempt at transitioning an industry to circular business models. Interviewee three reported that there is limited policy and there is uncertainty on which government department is responsible. This view is shared in a study of the Finish mining industry (Kinnunen & Kaksonen, 2019), in which the respondents emphasized the needs for unambiguous policy certainty. The study further concluded that the intricate nature of policies and contradicting departmental views, are creating barriers to the transition towards a circular economy in Finland. This study also suggested that sterner policy as well added regulations that mandate companies to derive use and profits from waste are necessary, which was contrastingly in direct contradiction to comments raised by the business practitioner and consultant groups interviewed. The respondents believed that SA has far too much policy that govern the mining sector and additional policies could be counterproductive. Based on the studies by Kinnunen and Kaksonen (2019) and Woźniak and Pactwa, (2018), the common narrative in the public domain is that specific circular economy regulations and policy is required to drive the circular economy transitions.

The MPRDA was cited as policy that is benefiting the mining sector and helps manage the environmental mitigation, however, a number of respondents reported that mining policy is not supportive of circular economy initiatives and therefore act as a barrier. A study in Poland on the circular economy transition in mining (Woźniak & Pactwa, 2018) observed similarly that mining regulations are also not supportive of a circular economy.

The lower level understanding and unclear definition of the circular economy is reported as a contributor to limited circular economy initiatives. Bechtel et al., (2013) determined that there was a lack of will to accept that a change is needed and although not the same as the findings in this study, there is a perceived link to the lack of understanding hampering transition to a circular economy. The people interviewed had a differing view on whether there was of lack of available skills to aid circular economy transitions, but the majority believed that the brain drain has depleted the required skills.

The availability of funding emerged as one of the leading barriers to circular economy initiatives and was raised by several of the interviewees. The risk averse nature of the South African mining sector has created a gap in funding for circular economy initiatives and is linked to the mining sectors view that initiatives that do not align with their core business of mineral extraction, should not be funded as long as risky economic circumstances prevail. Barr (2014) explained that most mining businesses are heavily leveraged and could possibly be a reason for limiting investment in projects that are perceived to not have a direct return to the bottom line. This position is reported as a limitation by Gorman (2018) due to the lack of metrics that demonstrate circular economy benefit and progress, therefore mining companies interpret this as circular economy being unachievable. The rhetoric is supporting the view of investors who believe there is a lack of value, therefore limiting funding in these areas (Ellen MacArthur Foundation, 2015).

Industries reluctance to invest can be related to the risk aversion, misalignment to core business and the linear nature of the mining sector, however the drive for new initiatives should be funded by government to de-risk initiatives. This approach will incentivise industry to change their view of circular economy. Unfortunately, the view of the interviewees is that the SA government is not funding enough circular economy projects, that will demonstrate the value of circularity and material flows. During the interviews only one project related to the circular economy and material flow analysis funded by DSI was reported. The Ellen MacArthur Foundation (2013) raised similar issues of the lack of funding for R&D, new processes and business models to support circular economy initiatives. The amount of funding available from government was an issue raised in a study on the rehabilitation of land disturbed by mining (Pomykała & Tora, 2017). This study reported that aside from the already limited funding, there will be an increased demand for government funding to rehabilitate these lands with circularity in mind. Important studies on circular economy in the mining sector state explicitly in the journal articles that the research conducted was not funded by private or public sector organisations (Gaziulusoy & Öztekin, 2019; Roberts & Geels, 2019; Tayebi-Khorami et al., 2019). This finding justifies and exemplifies the views of the interviewees on the lack of funding both in private and public sectors.

Availability of skills in South Africa has been a topic of concern for many years and is not limited to circular economy or the mining sector specifically. This lack of skills is driven largely by the “brain drain” associated with labour migrations from SA to the developed world (Radwan & Sakr, 2018).This is a view supported by the participants in this study, with respondent eight explaining that “although we are training more engineers, we are still short of the global norm”. Numerous studies have made similar findings in literature (de Ferreira & Fuso-Nerini, 2019; de Jesus et al., 2016; Dill, 2016; Essah & Andrews, 2016; Tayebi-Khorami et al., 2019), demonstrating the problem of skills availability is not only limited to the developing world. In a study on the circular economy in the banking sector, Dill (2016) found that skill availability was the leading barrier to successful implementation of circular economy processes, while Tayebi-Khorami (2019), provided a clear indication of the need to develop circular economy skills to enable mining waste reuse and recycling.

The mining industry’s core business is to extract resources from the ground to generate value for their shareholders. This business model is one developed since the start of mining and epitomises the linear economic way of thinking and is unfortunately manifesting as a barrier to implementation of circular economy projects. The study showed that mining firms consider circular economy initiatives as being fringe activities and generally dedicate limited resources to them because of the perceived detraction of focus and diversion of funds from core activities. Various studies have reported similar views (Barr, 2014; Bechtel et al., 2013; Dill, 2016; Kinnunen & Kaksonen, 2019; Lèbre et al., 2017b; Tost et al., 2018), citing mining industries "blinkered" focus on staying true to an extractive linear industry, as preventing adoption of circular economy initiatives. Interviewee five provided another perspective to the issue of core business, were he explained the possible link between the limited term of a mining company CEO's term in office and time required to deliver value in circular economy projects. This justifies that a CEO will focus on delivering shareholder value through focussed initiatives on their core business. Studies by (Kinnunen & Kaksonen, 2019; Laurence, 2011; Lèbre et al., 2017a) have all made similar conclusions. Tost (2018) further substantiated this view in his study, citing the coal industry and the shareholders view of sustainability as a threat to the core business of coal mines.

6.3.2 Drivers

The enablers or drivers of circular economy transitions in the mining sectors appeared to be limited with only 10 codes emerging from the interviews that could be assigned as drivers in contrast to over 22 barriers. Bechtel et al., (2013) made similar findings, with 165 barriers being identified as opposed to 56 drivers of the circular economy. The study was able to categorise drivers into four groups, viz.; Leadership, Collaboration, Motivation (through the concept itself) and Customer behaviour. The views of the interviewees will be discussed according to these categories.

Leadership

The reluctance of mining CEO's to invest in circular economy projects was cited as a barrier by almost all interviewees, however reference was made to some mining companies investigating the implementation of solar power farms, on baron mined land. This could potentially indicate a positive intervention by leadership to drive circular economy thinking. Interviewee 12 also highlighted the new business model adopted by Anglo Gold Ashanti that includes re-mining tailings dumps and this a typical example of visionary leadership that understands the benefits of material flows and circularity. Kinnunen and Kaksonon (2019) also found that despite the drive for staying true the company's core business, there are examples of backward integration to enhance recycling and refining capacity. The study cites a company called Boliden that has acquired recycling capacity to complement its material sourcing and resource recovery.

Collaboration

Initiatives like the Impact catalyst and the Green Engine are typical examples of collaborative efforts that translate into circular economy initiatives of potential value. The Impact Catalyst, although not popularised well, has all the key elements of collaboration with public and private partners within the mining industry as well as fringe industries. This project could be a key driver of circular economy transitions in the sector. International networks and collaborations within the EU and across the mining sector strengthen the success of implementing circular economy projects (Kinnunen, 2019). Abubakar (2018) explained that for effective circular economy transitions, all players within the ecosystem must partner and share information to streamline circular economy project implementation.

Motivation Through the Concept Itself

In Bechtel's framework (Bechtel et al., 2013), motivation through the concept is described as the energy that key individuals bring to a project because of their understanding of its benefits. This aligns to projects like the Impact Catalyst and the Green engine. The enthusiasm with which interviewee 6 spoke about these projects demonstrated the motivation she has to deliver on a circular economy because of her passion for the subject. Although she is not directly involved in the Impact Catalyst, but she is an active collaborator on the Green Engine project.

Customer Behaviour

An Anglo-American coal mine in Emalahleni has implemented a policy that forces their suppliers to ensure that all packaging that comes with a part or new equipment, must be removed from site. This policy enables the mine to utilise its purchasing power to reduce its non-biodegradable waste on site. Customers are increasingly more aware of the environmental impact of linear processes and are demanding products that have a smaller environmental footprint (Bechtel et al., 2013), with some mining companies also responding positively by embracing aspects of circularity. Other studies found that social and cultural alignment of shifting customer preferences are aiding the industrial drift toward a circular economy (de Jesus & Mendonça, 2018)

6.3.3 Summary of Findings on Niche Management

The mining socio-technical regime sees more barriers than opportunities, which is typical of early stage regimes that are recalcitrant to change (Geels, 2002). This is one of the key barriers to a successful change to the circular way of thinking within the mining sector. The limited niche management at the moment is characterised by internal reforms within the regime, which are slow and insubstantial. Increasing change impetus will require more destabilisation and greater competition from the micro level. To support and enable a swifter transition to the circular economy, there is a need for government level leadership to engage regimes to develop shared visions for the circular economy, facilitate learning and networking while offering protection of niche innovation (Schot & Geels, 2008).

The four key drivers of the circular economy are collaboration, leadership, customer behaviour and project related motivation. The industry must harness these drivers and provide the required level of support to exploit any potential windows of opportunity.

6.4 Imperatives for Change to Support the Transition

This research question was posed as a mechanism to determine what interventions need to be put in place to aid the transition to a circular economy. The discussion on this question aims to collate information gathered from interviews into the three levels using the MLP framework. This framework explains the three levels as landscape (macro), regime (meso) and niche (micro) levels. The theory explains the increasing levels of difficult to make changes as the intervention level moves from macro to micro (Geels, 2002). This study also describes the relationships between the three levels to bring about socio-technical change. Interviewees reported several changes that they viewed as necessary to transition the industry to a circular economy.

Landscape Developments Level

The landscape level is described as the level where change is slow and happens over a period of years or even decades. It is typically characterised by changes to policies that need to control and mandate the regime level (Geels et al., 2017). Based on this, the landscape level for this study is considered to be the country or government level. Players within the mining ecosystem are unable to impact the landscape level in the short term, but rather need to influence changes by processing through the niche and regime levels (Jackson et al., 2014). The interviewees in this study highlighted government and regulations as the primary barrier to the circular economy transitions and have also listed most of the changes required to be within this level.

The need for revised environmental regulations is a landscape intervention cited in the interviews, as well as the need for a dedicated department to take custodianship of the circular economy and prepare new policy to support transitions. According to MLP theory, the nested levels within landscape are the regimes and they generally react to pressure from landscape level and enable new interventions to enter (Geels, 2002). The pressure exerted by landscape policy interventions, disrupts the regime which provides opportunities for micro or firm level circular economy projects to enter the fore (Jackson et al., 2014). This literature supports the view of the interviewees, that critical policy certainty and enabling regulations will exert pressure on the industry and ultimately create a corridor for niche level circular economy transitions. However, for this to work effectively, niche level interventions must already be in the pipeline to be able to successfully exploit the window of opportunity while the regime is being destabilised.

Aside from policy and regulatory certainty, awareness at the macro level has great potential to bring about socio-technical changes (Abubakar, 2018) that could be relevant to circular economy. In Abubakar's (2018) study, he identified that the increased awareness at the landscape education level will aid circular economy within mining. This supports the views of the respondents in this study, who identified an increased awareness and understanding of the circular economy that will realise a broader spectrum of actors within the mining sector developing appreciation for the circular economy and thereby help destabilise embedded regimes.

Sociotechnical Regime Level

The extensive theory around MLP has explained the regime level as the most important level to navigate when bringing about socio-technical transitions (Borrello et al., 2020; El Bilali, 2019; Geels, 2011, 2020; Jackson et al., 2014). The regime is considered at mining industry level for this study and is an embedded regime due to the length of time that mining is being conducted in SA (Matinde et al., 2018). The SA mining regime level has adopted principles that were built on the linear economy foundations over years, therefore this paradigm is now extremely difficult to change. The results from this study supported this view as the majority of the interviewees reported that the lack of collaboration within the industry and the extractive nature of mining as their core business as barriers to change towards a circular economy.

The suggestions for the regime level changes were around awareness and data-based decision making. Respondents suggested that the industry coalesce to conduct a detailed analysis on the circular economy and the mining sector. This will improve awareness of circular economy but also destabilise the regime by removing any misconceptions and clarifying concerns around circular economy being a threat to the industry. The collaboration on key projects that created integrated and systematic approaches to transitioning to a circular economy, was also raised as a way to aid the transition. This type of initiatives are also supported by Abubakar (2018) and Ghisellini (2016) in their findings that meso level eco-industrial parks that support a circular economy, is an important tool to socio-technical changes related to circular economy. The projects that most closely align to Abubakar and Ghisellini's findings are the Green Engine and Impact Catalyst projects. However, the study revealed that these projects are not being driven effectively to realise impact. It is therefore imperative for the regime level projects to build momentum to force a change. For these initiatives, the sharing or infrastructure, technology and exchanging of waste across mining companies are required (Abubakar, 2018). The question that remains is whether the mining industry is ready for this level of collaboration and disruption to the regime?

Regime level organisations like the Minerals Council have a critical role to play in fostering collaboration but also to conceptualise meso level initiatives that will unite the industry towards a common circular economy goal. An analysis of the industry material flows, and the identification of risks of decreased demand or substitution will help the development of an appropriate industry wide circular economy strategy. This type of regime level interventions should be driven by the Minerals Council.

Technological Niche level

Niche or micro level initiatives, seed the change within the entire business environment and the MLP framework (Figure 3) is driven from niche level up (Geels, 2020). The Niche level is the most active and the easiest to stimulate change. These changes are what drives regime destabilisation but is most effective when landscape changes create a window of opportunity for firm level interventions towards socio-technical change (Geels, 2002).

The interviewees reported that increased awareness and adjustment of internal policy to align circular economy to ESG platforms will enable more recirculation of materials within the mines. The provision of training at the mine level will improve the understanding of circular economy and its benefits to the environment and business.

De Ferreira (2019) demonstrated that education is the cornerstone of any industry that wants to progress toward more circular processes. This study revealed micro level projects related to rubber recycling, process water reuse and remining of tailings as niche level novelties. These novelties are what will drive the entire three levels of the MLP framework. Geels (2002), explained that niche level projects require a level of shielding from the regime level selection processes, to allow these circular economy technologies to be able to develop without being forced to conform to socio-technical regimes. The micro level is considered the engine room for new ideas and innovations, these technicalities are then patched together by socio-technical regimes at the appropriate time. The regimes then stimulate landscape interventions that formalise the regimes through appropriate policy and regulatory intervention to eventually cement a socio-technical transition, as required for movement towards a circular economy (Geels, 2002; Jackson et al., 2014; Roberts & Geels, 2019). Figure 12 demonstrates this phenomenon graphically.

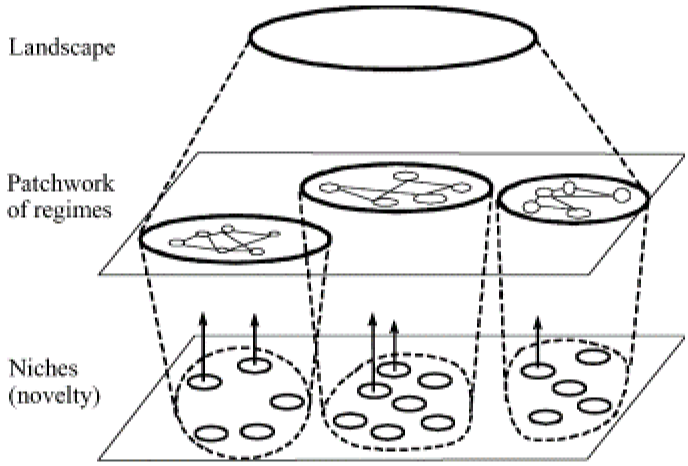

Figure 12: Nested Hierarchy of the MLP framework (Geels, 2002)

The nested hierarchy explains the linkages and reliance's of the three levels involved in the socio-technical transitions and provides a perspective on how this could impact a transition to circular economy in the mining sector.

In summary, the alignment of the findings to the MLP framework demonstrates how changes need to be implemented at the macro, meso and micro levels of society. The MLP framework is considered to be driven from a bottom up perspective (Schot & Geels, 2008) and therefore for effective change to happen, there is a need for more niche level competition to drive greater regime destabilisation. The current level of niche competition and emerging technicalities are insufficient to impact the socio-technical regimes.

In addition, several landscape level changes are recommended including changes to policy and regulations. As projects emerge from the niche level, changes at the landscape as a means of weakening the regime will be required, such as reforms to the Minerals Council so that it becomes a more direct agent of change.

6.5 Conclusion

The results revealed nine initiatives that are currently related to the circular economy in the mining sector. Most of the projects are R&D in nature and have yet to emerge into the industry. Industry level projects that require collaboration across multiple mining firms are required to successfully destabilise current regimes in the mining sector. Projects like the Green Engine and the Impact Catalyst are well positioned to drive the regime changes but require more collaboration and extensive marketing to realise the transition. Governments inactions and disorganised approach to circular economy policy, is creating uncertainty within the industry that is counterproductive to the circular economy transition journey. There is a need for a coordinated approach by multiple government departments to derive circular economy specific policy. However, there is also a need for a dedicated department to take ownership of the circular economy policy landscape for government. This policy uncertainty is not enabling action from business and needs urgent attention from government.

Barriers were easier to identify by the interviewees than drivers, demonstrated by an overwhelming 22 codes related to barriers being identified as opposed to only 10 for drivers. Government policy and regulatory environment was the dominant barrier and respondents believed that stricter environmental and waste management legislation and new circular economy policies are required.

The research revealed significantly higher number of barriers than drivers. The regulatory framework and governments involvements is considered a major hurdle towards rapid transition to a circular economy. The lack of policy certainty around waste management and environmental regulations in the mining sector is preventing leadership from seeing value in circular economy projects. Availability of skills was another interesting point raised by the interviewees that suggested that SA is lacking sufficient skills to support the circular economy. This problem is however not limited to SA, as research conducted in the developed world cited similar problems. The enablers to the circular economy identified were leadership foresight, collaboration customer behaviour that forces changes to support material circularity and circular economy projects that relate to peoples own motivation for circularity

CHAPTER 7. CONCLUSIONS

This chapter summarises the findings of the study in response to the research questions posed in line with the MLP framework. Key recommendations for the effective transition of mining sector to a circular economy are stated. The section also presents the limitations of the study as well as suggests future research that can add to this study.

7.1 Principal Findings

The circular economy is a framework that emerged a few decades ago but has only gained momentum over the last few years and has demonstrated the potential to transform the sustainability landscape to be less wasteful (Boulding, 1966). This study was positioned to develop a deeper understanding of circular economy in the mining sector and included interviews with participants from the industrial ecosystem, from academia, mining firms, government, and environmental consultants.

The MLP framework was applied in this study as a means of understanding the process of transition and identifying important developments within the three levels of socio-technical systems (Geels, 2020; Schot & Geels, 2008). This framework is part of the sustainability transitions theory (Geels, 2020; Markard et al., 2012; Ramos-Mejía et al., 2018) and explains that effective socio-technical change occurs as collaboration of the three levels of society, viz; landscape, regime and niche levels. Using this framework, the status, barriers, and drivers were identified and used to suggest management and governmental interventions that need to happen to aid the transition.

The definition of circular economy has been the subject of different studies (Esposito et al., 2018; Geisendorf & Pietrulla, 2018; Ghisellini et al., 2016) that have found that the interpretation of circular economy has an impact on the support offered to circular economy initiatives. The research identified two dominant definitions that prevailed and these related to material flows, and regeneration and recycling. Interestingly the content experts and the governmental official amongst the respondents understood circular economy to be about keeping resources in flow within the economy for as long as possible. While the consultants and business practitioners viewed circular economy to be predominantly about waste management and recycling. These different definitions foster different perspectives, with the latter definition introducing a limitation that manifests as circular economy initiatives on the ground being focused largely waste management and recycling.

The principal findings of the study are summarised below under the three research questions.

RESEARCH QUESTION ONE: What is the status of the Circular Economy in SA's mining industry?

The results indicated that there were only nine projects that could be related to circular economy activities in the mining sector and most of these projects are either at R&D or piloting stage. This suggested that there is a high probability that in the next year or two the landscape of circular economy projects implemented on the ground would be vastly different. There are some interesting initiatives implemented that optimises the circular economy ethos and links to various social imperatives that mines sought to deliver on.

Active projects that were discussed in the interviews dominate the niche (mine) level of implementation. If these projects are executed effectively the intended social, economic, and environmental value will be realised. However, it was clear from the results that the regimes are still very much linear in nature as this was concluded from the lack of coordinated industry level projects and initiatives (Abubakar, 2018; Bechtel et al., 2013; Kinnunen & Kaksonen, 2019). Although two industry level projects were discussed, viz; Green Engine and Impact Catalyst, there real impact on the ground cannot be ascertained. The lack of knowledge of these projects by all participants was a clear indication that the projects have not really gained momentum. For these projects to have a positive impact on the circular economy transition of the mining sector, a more inclusive approach to implementation must be adopted. The interviewees lack of knowledge of the Impact Catalyst, which claims to "Deliver positive socio-economic change aligned to the sustainable development goals" (*Impact Catalyst*, n.d.) is a concern and the CSIR should consider marketing this initiative better to allow it to gain traction in the industry.

The government interventions regarding the circular economy is limited to the DSI's plans that are metered out in the white paper and there appears to be a lack of consolidated interventions from government which are creating uncertainty on how to approach circular economy activities.

There appears to be some level of landscape pressure being applied through societies improved awareness of the environmental impacts of mining. Although government policy interventions and regulations are limited, they are contributing to applying pressure on the regimes. Unfortunately, these pressures are insufficient to significantly destabilise the regime. The evaluation of the responses from the interviewees have demonstrated that there is little evidence of niche management, highlighting limited leadership by government in supporting niche development and implementing the necessary regulatory reform. As a result, the transition is characterised by internal reforms within the regime, which are slow and insubstantial. Great impetus will require more destabilisation and greater competition from the micro level.

RESEARCH QUESTION TWO: What are the Barriers and Drivers for a Circular Economy Transition?

The research revealed significantly higher number of barriers than drivers. The regulatory framework and governments involvements is considered a major hurdle rapid transitions to a circular economy. The lack of policy certainty around waste management and environmental regulations in the mining sector is preventing leadership to see value in the circular economy projects. There was mixed opinion on the need for stricter policies to force circular economy transitions, however literature supports the implementation of harsher penalties and sterner policies to aid in the transition to a circular economy. Understanding of circular economy was another barrier that respondents believe are limiting support for circular economy projects at the level of CEO. There is a perception that circular economy is a deviation from core business activities of mines and therefore enjoys little support the from the C suit. This is exacerbated by the fact that mining company CEO's have limited terms in office and therefore dedicate all their energy in returning shareholder value as opposed to transitioning the industry to a circular economy.

Availability of skills was another interesting point raised by the interviewees that suggested that SA is lacking sufficient skills to support the circular economy. This is problems is not limited to SA as research conducted in the developed world cited similar problems.

Surprisingly, few drivers of the circular economy emerged during the interviews, however, those that were identified have high potential to support the transition. As much leadership was cited as barrier, it was also identified as driver in some instances. When leadership have the foresight and understanding of how the circular economy can benefit the firm and bring new business models to the fore, then it is a true enabler. Some SA gold mines have already embraced circularity of resources by including remining of tailings dumps into the next ten-year business strategies. Collaboration was critical identified from the study as well as supported in literature as an important tool for supporting the circular economy. Regime level projects are the best way to harness the collaborative energy to deliver the required changes that support circular economy at the niche level. Projects that enjoy enthusiasm from staff and leadership have an enabling effect. Projects like the Green Engines is one such project and if the industry can connect these energies, significant momentum can be generated on the project.

The mining socio-technical regime sees more barriers than opportunities, which is typical of early stage regimes, which are recalcitrant to change (Geels, 2002). This is one of the key problems with a successful change to the circular way of thinking within the mining sector. The limited niche management has resulted, the transition now is characterised by internal reforms within the regime, which are slow and insubstantial. Great impetus will require more destabilisation and greater competition from the micro level.

RESEARCH QUESTION THREE: What Must Change to Accelerate the Circular Economy?

The alignment of the findings to the MLP framework demonstrates how changes need to be implemented at the macro, meso and micro levels of society. The MLP framework is suggested to be driven from a bottom up perspective (Schot & Geels, 2008) and therefore for effective change to happen, there is a need for more niche level competition to drive greater regime destabilisation. The current level of niche competition and emerging technicalities are insufficient to impact the socio-technical regimes.

To place more impetus on regime destabilisation the most like initial changes required will be for the micro level to put more emphasis on the generation of new ideas that will eventually transition into mainstream an put pressure regime and landscape levels. The study found that key initiatives related to the circular economy, like recycling of rubber, process water and remining of tailings dumps are micro initiatives that must be incubated at the firm level to eventually transform the regimes which will eventually embed throughout the ecosystem by appropriate changes at the landscape level.

Sociotechnical regimes are more difficult to break, and in the case of the mining sector these regimes have been built on liner economic principles since the start of mining in SA. The interviewees all agreed that there is need for more industry level collaborations that aid in the destabilisation of these embedded regimes that ill allow niche level initiatives to emerge. Projects like the Green Engine and Impact catalyst are well suited to destabilise the regimes, but the appropriate industry level collaborations are critical to its success.

The recommended landscape level changes involve policy, regulations and politics that generally take longer to manifest. However, the study revealed that there is an urgent need for circular economy specific policy that will aid transitions. As projects emerge from the niche level the landscape will be forced to implement appropriate changes, however for this to happen the industry level must drive this through organisations like the Minerals council.

7.2 Research Limitations Restated

Although a qualitative study was the correct choice for exploratory research, a limitation of the study was the lack of quantitative trends, life cycle analysis and material flow accounting data that demonstrate the status of Circular Economy transition (Lèbre et al., 2017a). This is therefore a recommendation for future study. Access to key individuals were a challenge and therefore the senior mine employees and executive leadership do not constitute the respondent categories. The time pressures associated with an MBA study limited the number of respondents to 12 and to participants within the researcher's network that were willing to engage in interviewees. With added time the research would have preferred to engage a wider range of respondents to get a more diverse view of the problems in the mining sector.

The impersonal online platforms may have posed a limitation on the engagement on some of the topics. Although the researcher probed and prompted respondents to engage with key issues, there is a possibility that the lack of a physical present could have limited this.

7.3 Recommended Future Research

The mining sector in SA is large and diverse and a futures study should be conducted to categorise the study into the various minerals that are mined in SA. This study was conducted on a holistic "mining sector "perspective and there is a possibility that the barriers and drivers maybe different in different mineral sectors.

Material flow analysis (MFA) was a key concepts discussed by respondents and although there are some high-level studies being conducted, there is a need to conduct specific MFA to each sector with the specific aim of identify opportunities to implement circularity principles within the value chains. Using this material flow accounting the researcher can make recommendations on how to impact and respond to resource scarcity and business model diversification.

During the study it was apparent that some industry actors view circular economy as threat to the mining business, and therefore a detailed study that aims to develop a framework for leaders in the mining sector to test the impact of potential circular economy projects on their business models.

REFERENCES

Abubakar, F. (2018). *An investigation into the drivers, barriers and policy implications of circular economy using a mixed-mode research approach* (Issue March). University Sheffield.

Allan, R. (1995). Introduction: Sustainable mining in the future. In *Journal of Geochemical Exploration* (Vol. 52, Issues 1–2, pp. 1–4). Elsevier. https://doi.org/10.1016/0375-6742(94)00051-C

Anawar, H. M. (2015). Sustainable rehabilitation of mining waste and acid mine drainage using geochemistry, mine type, mineralogy, texture, ore extraction and climate knowledge. *Journal of Environmental Management (Tier 3)*, *158*, 111–121. https://doi.org/10.1016/j.jenvman.2015.04.045

Arora, M., Raspall, F., Cheah, L., & Silva, A. (2020). Buildings and the circular economy: Estimating urban mining, recovery and reuse potential of building components. *Resources, Conservation and Recycling*, *154*(November 2019), 104581. https://doi.org/10.1016/j.resconrec.2019.104581

Balanay, R., & Halog, A. (2016). Charting policy directions for mining's sustainability with circular economy. *Recycling*, *1*(2), 219–231. https://doi.org/10.3390/recycling1020219

Balanco, T. (2015). *A Continuous value proposition – Waste created by food manufacturing companies and the conversion of bio- waste into biogas and bio-fertiliser .* (Issue November). University of Pretoria.

Barr, C. (2014). The influence of sustainability metrics on investment capital in the South African mining industry. In *Gordon Institute of Business Science, University of Pretoria* (Issue November). University of Pretoria.

Bechtel, N., Bojko, R., & Völkel, R. (2013). *Be in the loop: Circular economy & strategic sustainable development*. Blekinge Institute of Technology Karlskrona,.

Bichueti, R. S., Gomes, C. M., Kneipp, J. M., Motke, F. D., Perlin, A. P., & Kruglianskas, I. (2018). Water use management in the mining industry: A comparison based on company size. *Journal of Environmental Accounting and Management (Tier 3)*, *6*(2), 135–147. https://doi.org/10.5890/JEAM.2018.06.005

Bignozzi, M. C., & Sandrolini, F. (2006). Tyre rubber waste recycling in self-compacting concrete. *Cement and Concrete Research*, *36*(4), 735–739. https://doi.org/10.1016/j.cemconres.2005.12.011

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research (Tier 2)*, *19*(4), 426–432. https://doi.org/10.1108/QMR-06-2016-0053

Borrello, M., Pascucci, S., & Cembalo, L. (2020). Three propositions to unify circular economy research: A review. *Sustainability*, *12*(10), 4069. https://doi.org/10.3390/su12104069

Boulding, K. . (1966). The economics of the coming spaceship Earth. In H. Jarrett (Ed.), *Environmental quality issues in a growing economy* (pp. 3–14). Johns Hopkins University Press.

Breytenbach, M. (2016). New South African solution to recycle waste mining tyre stockpiles. *Minning Weekly*. https://www.miningweekly.com/article/new-south-african-solution-to-recycle-waste-mining-tyre-stockpiles-2016-02-05/rep_id:3650

Chakravarthy, C., Chalouati, S., Chai, Y. E., Fantucci, H., & Santos, R. M. (2020). Valorization of kimberlite tailings by carbon capture and utilization (CCU) method. *Minerals*, *10*(7), 1–18. https://doi.org/10.3390/min10070611

Chul, S., Se, K., Oh, J., Min, S., Sang, O., & Lee, P. (2017). In situ reclamation of closed coal mine waste in Korea using coal. *Applied Biological Chemistry*, *60*(3), 265–272. https://doi.org/10.1007/s13765-017-0275-y

Chung, K. H., & Hong, Y. K. (2009). Weathering properties of elastic rubber concrete comprising waste tire solution. *Polymer Engineering and Science*, *49*(4), 794–798. https://doi.org/10.1002/pen.21312

Creamer, M. (2012, July). Global mining drives 45%-plus of world GDP – Cutifani. *Mining Weekly*. https://m.miningweekly.com/article/global-mining-drives-45-plus-of-world-gdp-cutifani-2012-07-04/rep_id:3861

Davies, C. F., Berman, E., Pillay, D., & Sonnenbergs, E. N. (2018). *Mining in South Africa: overview*.

de Ferreira, A. C., & Fuso-Nerini, F. (2019). A framework for implementing and tracking circular economy in cities: The case of Porto. *Sustainability*

(Switzerland) (Tier 2), *11*(6), 1–23.

de Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2016). Eco-innovation in the transition to a circular economy: An analytical literature review. *Journal of Cleaner Production (Tier 2)*, *172*, 2999–3018.

de Jesus, A., & Mendonça, S. (2018). Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. *Ecological Economics (Tier 3)*, *145*, 75–89.

Department of Environmental Affairs. (2011). National waste management strategy. In *National Waste Management Strategy* (Issue November). https://www.environment.gov.za/sites/default/files/docs/nationalwaste_management_strategy.pdf

Dicks, H. (2016). The philosophy of biomimicry. *Philosophy and Technology*, *29*(3), 223–243. https://doi.org/10.1007/s13347-015-0210-2

Dill, H. (2016). *Advantages, enablers and barriers to implementing circular economic principles in South African financial services organisations* (Issue November). University of Pretoria.

DSI. (2019). *White paper on science , technology and innovation* (Issue March).

El Bilali, H. (2019). The multi-level perspective in research on sustainability transitions in agriculture and food systems: A systematic review. *Agriculture*, *9*(4). https://doi.org/10.3390/agriculture9040074

ElFouly, H. A., & El Aziz, N. A. (2017). Physical quality of life benchmark for unsafe slums in Egypt. *Sustainability in Environment*, *2*(2), 258. https://doi.org/10.22158/se.v2n2p258

Ellen MacArthur Foundation. (2013). Toward the circular economy: Accelerating the scale-up across global supply chains. In *EMF*.

Ellen MacArthur Foundation. (2015). Towards a circular economy: business rationale for an accelerated transition. In *EMF*.

Esposito, M., Tse, T., & Soufani, K. (2018). The circular economy: An opportunity for renewal, growth, and stability. *Thunderbird International Business Review (Tier 2)*, *60*(5), 725–728.

Essah, M., & Andrews, N. (2016). Linking or de-linking sustainable mining practices and corporate social responsibility? Insights from Ghana. *Resources Policy (Tier 2)*, *50*, 75–85. https://doi.org/10.1016/j.resourpol.2016.08.008

Florin, N., Madden, B., Sharpe, S., Benn, S., Agarwal, R., Perey, R., & Giurco, D. (2015). Shifting business models for a circular economy: Metals management for multi-product-use cycles. In *Journal of Industrial Ecology (Tier 2)* (Vol. 10, Issues 1–2).

Gaziulusoy, Ï., & Öztekin, E. E. (2019). Design for sustainability transitions: Origins, attitudes and future directions. *Sustainability*, *11*(13). https://doi.org/10.3390/su11133601

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy (Tier 4)*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. In *Environmental Innovation and Societal Transitions* (Vol. 1, Issue 1, pp. 24–40). Elsevier B.V. https://doi.org/10.1016/j.eist.2011.02.002

Geels, F. W. (2020). Micro-foundations of the multi-level perspective on socio-technical transitions: Developing a multi-dimensional model of agency through crossovers between social constructivism, evolutionary economics and neo-institutional theory. *Technological Forecasting and Social Change (Tier 3)*, *152*(October 2018). https://doi.org/10.1016/j.techfore.2019.119894

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, *36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). The Socio-Technical Dynamics of Low-Carbon Transitions. *Joule*, *1*(3), 463–479. https://doi.org/10.1016/j.joule.2017.09.018

Geisendorf, S., & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review (Tier 2)*, *60*(5), 771–782.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production Tier 2)*, *114*, 11–32. http://dx.doi.org/10.1016/j.jclepro.2015.09.007

Gorman, M. R., & Dzombak, D. A. (2018). A review of sustainable mining and resource management: Transitioning from the life cycle of the mine to the life cycle of the mineral. *Resources, Conservation and Recycling*, *137*, 281–291. https://doi.org/10.1016/j.resconrec.2018.06.001

Guest, G., MacQueen, K. M., & Namey, E. E. (2012). *Applied thematic analysis*. SAGE Publications.

Gumbo, T. (2013). *Towards a green energy revolution in Africa: Reflections on waste-to-energy projects*. http://www.ai.org.za/wp-content/uploads/downloads/2013/12/Towards-a-Green-Energy-Revolution-in-Africa-Reflections-on-Waste-to-energy-projects1.pdf

Hofstee, E. (2006). *Constructing a good dissertation*. Exactica.

Hueting, R. (1990). The Brundtland report. A matter of conflicting goals. *Ecological Economics (Tier 3)*, *2*(2), 109–117. https://doi.org/10.1016/0921-8009(90)90002-C

Impact Catalyst. (n.d.). Retrieved November 12, 2020, from https://www.impactcatalyst.co.za/

Jackson, M., Lederwasch, A., & Giurco, D. (2014). Transitions in theory and practice: Managing metals in the circular economy. *Resources*, *3*(3), 516–543. https://doi.org/10.3390/resources3030516

Johnson, P. (1999). *The civilization of ancient Egypt*. Harper Collins.

Kesler, S. E. (2007). Mineral supply and demand into the 21st century. *Workshop on Deposit Modeling, Mineral Resource Assessment, and Sustainable Development.*, 55–62. http://www.census.gov/ipc/www/

Kinnunen, P. (2019). *Towards circular economy in the mining industry : Implications of institutions on the drivers and barriers for tailing valorisation* (Issue May). Tampere University.

Kinnunen, P., & Kaksonen, A. (2019). Towards circular economy in mining: Opportunities and bottlenecks for tailings valorization. *Journal of Cleaner Production (Tier 2)*, *228*, 153–160.

Kitahara-Frisch, J. (1978). Stone Tools as Indicators of Linguistic Abilities in Early Man. *Annals of the Japan Association for Philosophy of Science*, *5*(3), 101–109. https://doi.org/10.4288/jafpos1956.5.101

Krausmann, F., Wiedenhofer, D., Lauk, C., Haas, W., Tanikawa, H., Fishman, T., Miatto, A., Schandl, H., & Haberl, H. (2017). Global socioeconomic material stocks rise 23-fold over the 20th century and require half of annual resource use. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(8), 1880–1885. https://doi.org/10.1073/pnas.1613773114

Lachman, D. A. (2013). A survey and review of approaches to study transitions. *Energy Policy (Tier 2)*, *58*, 269–276. https://doi.org/10.1016/j.enpol.2013.03.013

Laurence, D. (2011). Establishing a sustainable mining operation: An overview. *Journal of Cleaner Production*, *19*(2–3), 278–284. https://doi.org/10.1016/j.jclepro.2010.08.019

Lèbre, É., Corder, G. D., & Golev, A. (2017a). Sustainable practices in the management of mining waste: A focus on the mineral resource. *Minerals Engineering*, *107*, 34–42. https://doi.org/10.1016/j.mineng.2016.12.004

Lèbre, É., Corder, G., & Golev, A. (2017b). The role of the mining industry in a circular economy: A framework for resource management at the mine site level. *Journal of Industrial Ecology (Tier 2)*, *21*(3), 662–672.

Lewandowski, M. (2016). Designing the business models for circular economy-towards the conceptual framework. *Sustainability (Switzerland) (Tier 2)*, *8*(1), 1–28.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production (Tier 2)*, *115*, 36–51.

Lin, S., Liu, R., Wu, M., Hu, Y., Sun, W., Shi, Z., Han, H., & Li, W. (2020). Minimizing beneficiation wastewater through internal reuse of process water in flotation circuit. *Journal of Cleaner Production*, *245*, 118898. https://doi.org/10.1016/j.jclepro.2019.118898

Lucas, A. (1927). Copper in ancient Egypt. *The Journal of Egyptian Archaeology*, *13*(1), 162–170. https://doi.org/10.1177/030751332701300130

Maharajh, D., Grewar, T., Neale, J., & van Rooyen, M. (2018). Mine Water: A Resource for the Circular Economy in South African Mining Communities. In J. Goodwill & D. Van Zyl (Eds.), *Proceedings of Mine Water Solutions 2018* (pp. 349–362).

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Marshall, B., Cardon, P., Poddar, A., & Fontenot, R. (2013). Does sample size matter in Qualitative research: A review of qualitative interviews in IS research. *Journal of Computer Information Systems*, *51*(1), 11–22.

Martins, J. C. (2017). Mine Water Coordinating Body established in South Africa – 2030 Water Resources Group – World Bank Group. *Corprate News*. https://www.2030wrg.org/mine-water-coordinating-body-mwcb-established-in-south-africa/

Mathews, J. A., & Tan, H. (2011). Progress toward a circular economy in China: The drivers (and inhibitors) of eco-industrial initiative. *Journal of Industrial Ecology (Tier 2)*, *15*(3), 435–457.

Matinde, E., Simate, G. S., & Ndlovu, S. (2018). Mining and metallurgical wastes: A review of recycling and re-use practices. *Journal of the Southern African Institute of Mining and Metallurgy*, *118*(8), 825–844. https://doi.org/10.17159/2411-9717/2018/v118n8a5

Mullerat, B. (2000). Environmental liability arising from a mining accident in Spain: the disaster of Donana On. *Mineral Resources Engineering*, *9*(1), 89–100.

Neingo, P. N., & Tholana, T. (2016). Trends in productivity in the South African gold mining industry. *Journal of the Southern African Institute of Mining and Metallurgy*, *116*(3), 283–290. https://doi.org/10.17159/2411-9717/2016/v116n3a10

Njini, F. (2020). Hydrogen to Fuel Giant Mining Trucks in Green Shift by Anglo. *Bloomberg Green*, 11–13.

Packey, D. J. (2012). Multiproduct mine output and the case of mining waste utilization. *Resources Policy (Tier 2)*, *37*(1), 104–108. https://doi.org/10.1016/j.resourpol.2011.11.002

Pactwa, K., Woźniak, J., & Dudek, M. (2020). Coal mining waste in Poland in reference to circular economy principles. *Fuel*, *270*(February). https://doi.org/10.1016/j.fuel.2020.117493

Parameswaran, K. (2017). Energy use, conservation and eco-efficiency considerations in the primary copper industry. *Conference of Metallurgists*.

Parameswaran, K. (2016). Sustainability considerations in innovative process development. *Innovative Process Development in Metallurgical Industry.*, 257–280.

Pearce, D. ., & Turner, R. . (1990). *Economics of Natural Resources and the Environment*. Johns Hopkins University Press.

Pienaar, C., Basson, L., Williams, Q., & Fordyce, N. (2019). Waste: Market Intelligence Report 2019. In *Waste*.

Pomykała, R., & Tora, B. (2017). Circular economy in mineral processing. *E3S Web of Conferences*, *18*, 1–6.

Radwan, A., & Sakr, M. (2018). Exploring ‘brain circulation’ as a concept to mitigate brain drain in Africa and improve EU–Africa cooperation in the field of science and technology. *South African Journal of International Affairs*, *25*(4), 517–529. https://doi.org/10.1080/10220461.2018.1551151

Ramos-Mejía, M., Franco-Garcia, M. L., & Jauregui-Becker, J. M. (2018). Sustainability transitions in the developing world: Challenges of socio-technical transformations unfolding in contexts of poverty. *Environmental Science and Policy*, *84*(March 2016), 217–223. https://doi.org/10.1016/j.envsci.2017.03.010

Rico, M., Benito, G., Salgueiro, A. R., & Pereira, H. G. (2008). Reported tailings dam failures A review of the European incidents in the worldwide context. *Journal of Hazardous Materials*, *152*(2), 846–852. https://doi.org/10.1016/j.jhazmat.2007.07.050

Rip, A., & Kemp, R. (1998). Technological change. In S. Rayner & E. Malone (Eds.), *Human choice and climate change* (pp. 327–399). Battelle Press. https://www.dphu.org/uploads/attachements/books/books_2786_0.pdf

Ritzén, S., & Sandström, G. Ö. (2017). Barriers to the circular economy - Integration of perspectives and domains. *Procedia CIRP*, *64*, 7–12.

Roberts, C., & Geels, F. W. (2019). Conditions for politically accelerated transitions: Historical institutionalism, the multi-level perspective, and two historical case studies in transport and agriculture. *Technological Forecasting and Social Change*, *140*(November 2018), 221–240. https://doi.org/10.1016/j.techfore.2018.11.019

Rösner, T., & Van Schalkwyk, A. (2000). The environmental impact of gold mine tailings footprints in the Johannesburg region, South Africa. *Bulletin of Engineering Geology and the Environment*, *59*(2), 137–148. https://doi.org/10.1007/s100640000037

Rumpold, R., & Antrekowitsch, J. (2012). Recycling of PGMs from automotive catalysts by an acidic leaching process. *The Southern African Institute of Mining and Metallurgy Platinum 2012*, 695–714.

Saidani, M., Kendall, A., Yannou, B., Leroy, Y., & Cluzel, F. (2019). Closing the loop on platinum from catalytic converters: Contributions from material flow analysis and circularity indicators. *Journal of Industrial Ecology*, *23*(5), 1143–1158. https://doi.org/10.1111/jiec.12852

Saunders, M., & Lewis, P. (2018). *Doing research in business and management : an essential guide to planning your project* (2nd ed.). Pearson.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technology Analysis and Strategic Management*, *20*(5), 537–554. https://doi.org/10.1080/09537320802292651

Sharma, S., Stelter, B., Davidson, G., & Petersen, I. (2015). *Mining & Metals in a Sustainable World 2050* (Issue September). http://www3.weforum.org/docs/WEF_MM_Sustainable_World_2050_report_2015.pdf

NEMA: Waste Act 59 (2008), 525 Government Gazette 4 (2009). https://doi.org/102GOU/B

Sturdy, J., & Cronje, C. J. (2014). The levels of disclosure relating to mine closure obligations by platinum mining companies. *South African Journal of Economic and Management Sciences*, *20*(1), 1–8.

Swart, E. (2003). The South African legislative framework for mine closure. *Mine*

Closure for Sustainable Development.

Tayebi-Khorami, M., Edraki, M., Corder, G., & Golev, A. (2019). Re-thinking mining waste through an integrative approach led by circular economy aspirations. *Minerals*, *9*(5).

Thoka, B. (2020). *Policy and regulation as enablers for early childhood development centres in townships and informal settlements* [University of Pretoria]. https://doi.org/10.1155/2010/706872

Tost, M., Hitch, M., Chandurkar, V., Moser, P., & Feiel, S. (2018). The state of environmental sustainability considerations in mining. *Journal of Cleaner Production*, *182*, 969–977. https://doi.org/10.1016/j.jclepro.2018.02.051

Toteva, V., & Stanulov, K. (2020). Waste tires pyrolysis oil as a source of energy: Methods for refining. *Progress in Rubber, Plastics and Recycling Technology*, *36*(2), 143–158. https://doi.org/10.1177/1477760619895026

Van Driesche, R. G., Carruthers, R. I., Center, T., Hoddle, M. S., Hough-Goldstein, J., Morin, L., Smith, L., Wagner, D. L., Blossey, B., Brancatini, V., Casagrande, R., Causton, C. E., Coetzee, J. A., Cuda, J., Ding, J., Fowler, S. V., Frank, J. H., Fuester, R., Goolsby, J., … van Klinken, R. D. (2010). Classical biological control for the protection of natural ecosystems. In *Biological Control* (Vol. 54, Issue SUPPL. 1, pp. S2–S33). Academic Press. https://doi.org/10.1016/j.biocontrol.2010.03.003

Vries, J. De. (1994). The industrial revolution and the industrious revolution. *Journal of Economic History*, *54*(2), 249–270.

Vutha, A. (2020). *Dealing with performance-based health technology assessment outcomes for medical devices: A South African perspective* [University of Pretoria]. https://doi.org/10.1155/2010/706872

Watson, J. H. P., & Beharrell, P. A. (2006). Extracting values from mine dumps and tailings. *Minerals Engineering*, *19*(15), 1580–1587. https://doi.org/10.1016/j.mineng.2006.08.014

World Water Week 2019 - Water for society: including all | Anglo American. (n.d.). Retrieved November 12, 2020, from https://www.angloamerican.com/about-us/our-stories/world-water-week-2019-water-for-society-including-all

Woźniak, J., & Pactwa, K. (2018). Overview of polish mining wastes with circular economy model and its comparison with other wastes. *Sustainability (Switzerland) (Tier 2)*, *10*(11).

Zeng, X., Mathews, J. A., & Li, J. (2018). Urban mining of e-waste is becoming more cost-effective than virgin mining. *Environmental Science and Technology (Tier 3)*, *52*(8), 4835–4841.

Zhang, J., Liang, Y., & Harpalani, S. (2016). Optimization of methane production from bituminous coal through biogasification. *Applied Energy*, *183*, 31–42. https://doi.org/10.1016/j.apenergy.2016.08.153

Zhao, Y., Zang, L., Li, Z., & Qin, J. (2012). Discussion on the model of mining circular economy. *Energy Procedia*, *16*, 438–443.

Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2012). *Business research methods* (8th ed.). South-Western College Pub.

Appendix I: Informed Consent Form

Gordon Institute of Business Science
University of Pretoria

Dear Participant

I am currently a student at the University of Pretoria's Gordon Institute of Business Science where I am undertaking my research towards the mini dissertation, completing my research in partial fulfilment of an MBA.

My research covers the adoption of the circular economy's principles and approach by the South African mining sector. You are requested to participate in this research as a key informant on the present status of the circular economy and waste management more broadly. Our interview is expected to last about 40 minutes. The questions have been designed to assist me in understanding the sector, develop some insights int the potential benefits of a circular economy transition and identify the key barriers/drivers of the transition.

Your participation is voluntary, and you can withdraw at any time without penalty. All data will be reported without identifiers. If you have any concerns, please contact my supervisor or me. Our details are provided below.

Participant Name:

Signature of participant: ________________________________

Date: _______________

Researcher Name: **Dheepak Maharajh**

Email: 19385715@mygibs.co.za

Phone: 0826508542

Signature of researcher: _______________________________

Date: 12 August 2020

Research Supervisor Name: **David R Walwyn**

Email: david.walwyn@up.ac.za

Research Supervisor Signature ______________________________

Date: 12 August 2020

Appendix II: Semi-structured Research Questionnaire

Gordon Institute of Business Science
University of Pretoria

Section 1: Background Information on Interviewee

1. What is the name of your organisation?
2. What sector does your company fall into?
3. What is your role in the organisation?
4. What is your qualification level and how many years have you been in this company and how many years of experience do you have in total?
5. What mineral does your company mine or work with?
6. What is your interpretation of the Circular Economy?

Section 2: Initiatives Status

1. Can you list some company initiatives on the circular economy or waste management that has been started or planned? This can be in your organisation as well as in other organisations that you may know off.
2. How has these initiatives proceeded until today? Are they on track, delayed or ahead of schedule?
3. What are the reasons for its status or what do you think is the reasons for its status?
4. What are the views of your respective stakeholders towards these initiatives?
5. What industry-level CE initiatives are you aware of (please describe these)?
6. Are these initiatives formally supported by individual organisations?
7. What are global trends and initiatives that you are aware of with regards to CE and waste management in the mining sector?

Section 3: Barriers and Drivers

1. Can you explain what you believe are the barriers to transition to a CE economy in mining sector?
2. Are sufficient skills and knowledge available in South Africa to aid the transition to a circular economy?
3. What are the government policies or initiatives that support or hinder the adoptions of CE in the industry?
4. How do you believe a shift to CE principles will benefit the mining community and society as a whole?
5. What do you believe are the most pertinent benefits of the circular economy to the mine, the industry, and the country?

Section 4: What needs to change?

1. What needs to happen at the level of the mine? What programs need to be put in place?
2. What needs to happen at the industry level? How should the industry organise itself to aid the transition?
3. What should government and other stakeholder do to assist the transition?
4. What needs to happen at the global level to assist the CE transition?

Appendix III: Non-Disclosure Agreement for Transcription Services

You have been hired to transcribe for Dheepak Maharajh on the research project "A transition of South Africa's mining sector to the Circular Economy: Status, drivers, barriers and benefits".

The ethical guidelines of this study require that you read and sign this form, signifying that you are willing to enter into a confidentiality agreement with respect to data collected for the study.

The audio recordings you will receive will likely contain identifying markers of the respondents as well as names of third parties (for instance colleagues, family members and/or acquaintances of participants). To protect confidentiality, you are to remove all identifiers of third parties and or respondents. You will ensure that all records, transcripts and always kept confidential (ie., materials are never left unattended and are secured when not being used). By signing below, you agree not to reveal any information about what is contained in the audio recordings or written transcripts. Furthermore, you agree not to discuss anything regarding the respondents, or the data collected in this study with anyone other than Dheepak Maharajh

By Signing this document, you are indicating that you have read and understood the above agreement and you will follow all specified conditions.

Full Names: ____

Contact Number: ____

Contact E-mail: ____

Signature: ____________________________________

Date: ________________________

Appendix IV: Research Ethics Approval

Gordon Institute of Business Science
University of Pretoria

Ethical Clearance Approved

Dear Dheepak Maharajh,

Please be advised that your application for Ethical Clearance has been approved.
You are therefore allowed to continue collecting your data.
We wish you everything of the best for the rest of the project.

Ethical Clearance Form

Kind Regards

This email has been sent from an unmonitored email account. If you have any comments or concerns, please contact the GIBS Research Admin team.

Appendix V: List of Codes Used

Code	Grounded	Density	Code Groups
Anglo's Green engine	4	0	Initiative
Authority	1	0	Hindrances
Available mineral deposit	2	0	Hindrances
Available skill	10	1	Hindrances Manpower
Available technology	3	0	Hindrances
Awareness	3	0	Needed changes Hindrances
Barriers to circular economy Initiatives	90	2	
Big mining firms	1	0	Hindrances
Blue Solar	1	0	Initiative
Brain drain	3	0	Manpower
Brain gain	3	0	Manpower
Change business model	3	0	Benefit Needed changes
Circular Economy	27	11	Circular Economy
Circular economy indicators	4	2	Initiative Circular Economy
Clean or Renewable energy	1	0	Circular Economy
Closed thinking	1	0	Circular Economy
Coal discard to energy	7	0	Initiative
Competitiveness	1	0	Hindrances
Conservation and transition	2	0	Circular Economy
Cost saving	14	0	Benefit Drivers
Custodians	1	0	Needed changes
Definition of the Circular Economy	18	10	Circular Economy
Demonstrate the circular economy concept works	1	0	
Distance sensitive	1	0	Circular Economy
Drivers to circular economy initiative	25	2	Drivers
Eco-friendly package design	1	0	Initiative
Economic factor	6	1	Benefit Drivers
Economic growth	13	2	Benefit Drivers
Employing expert	1	0	Needed changes
Enforcement	2	1	Hindrances
Focus	12	0	Needed changes Hindrances
Funding	12	1	Government Needed changes Hindrances
Funding initiatives to assit circular economy transitions	5	1	

Geothermal to produce methanol	2	0	Initiative
Global Initiatives	10	1	
Government	25	2	Hindrances
Governments positive intent	2	0	Government
Human waste	2	0	Hindrances
Impact Catalyst	4	0	Initiative
Implementation	2	0	Government Needed changes
Incentives	1	0	Benefit Hindrances
Industry	9	1	
Industry level initiatives	7	0	
Initiatives	60	2	
Innovation	2	0	Needed changes
Job creation and security	6	0	Benefit Government
Lack of industry level coordination	1	0	
Lack of significant Initiative in Mining	1	0	
Macro level - County Level	11	0	Needed changes
Manpower	15	1	
Market	1	0	Drivers
Market incentives	1	0	Hindrances
Material Flow Analysis	3	0	Initiative
Materials Recovery Facility	1	0	Initiative
Meso level/ industry level	11	0	Needed changes
Micro level- Mine level	19	0	Needed changes
Mine closure and future land use	3	0	Initiative
Mineral associated with circular economy initiatives	3	0	
Mineral beneficiation	1	0	Initiative
Minerals Council	4	0	
Mining waste	7	1	Initiative
Nature of industry	1	0	Hindrances
Needed changes	45	1	
Not core business	12	0	Hindrances
Opportunities in Circular Economy	3	2	Government Needed changes
Partnership	8	0	Government Needed changes Hindrances
Positive reputation for doing good	1	0	
Post mine closure	3	0	
Pressure	1	0	Hindrances
Preventing environmental damage from waste	5	0	Benefit
Profitability	4	0	Benefit
Prosperity focused	1	0	Circular Economy

Quality	1	0	Needed changes
Reason for change	2	0	Drivers
Reason for initiative Status	8	0	
Recycling	13	1	Initiative Circular Economy
Reduce waste generation	1	1	Circular Economy
Reducing mining	2	0	Needed changes
Regulations	34	1	Initiative Government Needed changes Drivers Hindrances
Relationship	1	0	Drivers
Remote skills	2	0	Manpower
Replacement	1	0	Initiative
Required material	1	0	Hindrances
Resource availability	1	0	Benefit
Re-use	15	1	Initiative Circular Economy Drivers
Risk	1	0	Hindrances
Road map	1	0	
Sectorial Integration	2	0	Needed changes
Security and scarcity	1	1	Circular Economy Drivers
Security of supply	1	1	Circular Economy Drivers
Sewage sludge	2	0	Initiative
Skills development programs	1	0	Hindrances
Slag treatment	1	0	Initiative
Socio-economic initiatives	5	0	
Specialisation	1	0	Manpower
Stakeholder views	2	0	
Status of initiatives	16	0	Initiative
Strategy	1	0	
Sustainability	14	0	Benefit Government Circular Economy
Tailing storage facilities	3	0	Initiative
Targeting the correct audience	2	0	Needed changes
Technology maturity and complexity	1	0	Hindrances
Threat on employment	1	0	Hindrances
Threat to mining industry	1	0	Hindrances
Training	3	0	Needed changes
Understanding circular economy	8	2	Needed changes Hindrances
Urban mining	4	0	Initiative
Using underground water	1	0	Initiative

Value creation	5	0	Benefit Drivers
Value extraction	1	0	Initiative
View of stakeholders	18	1	Government
Waste beneficiation	19	2	Drivers
Waste finding	1	0	Needed changes
waste research development and innovation	1	0	Initiative
Waste streams	7	0	Initiative
Waste to Energy	9	0	
Wastewater treatment	2	0	Initiative
What determine meaning	1	0	
Where needed	2	0	Manpower
Zero carbon emission	2	0	

Appendix VI: List of Interviewees

No	Position	Grouping	Place of Employment
1	Project Developer	Consultant	Harambe Energy
2	Managing Director	Consultant	4e Innovation
3	Principal Researcher	Content Expert	Council for Scientific and Industrial Research
4	Environmental Manager	Business Practitioner	Anglo American
5	Head of Business Development	Consultant	Ukwazi Mining Studies
6	Manager	Content Expert	Mintek
7	Research Associate	Content Expert	University of Pretoria
8	Research Professor	Content Expert	University of Cape Town
9	MBA Student	Business Practitioner	University of Cape Town
10	Director	Government Official	Department of Science and Technology
11	Environmental Manager	Business Practitioner	Mbuyelo Coal
12	VP: Sustainability	Business Practitioner	Anglo Gold Ashanti