Applying the systems of innovation approach to the South African mine waste management sector

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DECLARATION

I, Katlego Magoro, declare that this research article is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the Graduate School of Business Administration, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Katlego Simon Magoro

Signed at ………Paulshof……………………………………

On the …………13th............... day of ………June...... 2018...
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ABSTRACT

The purpose of this study is to investigate how the South African mining sector can use the Systems of Innovation Approach to minimise mine waste and grow the sector’s contribution to the green economy. The problem statement was investigated through two research questions:

First research question: Does the South African mine waste sector have the science and technology capability to reduce the reliance on waste to landfill disposal? If so, how are the stakeholders organised and interact to enable innovation in mine waste management?

Second research question: How can the current waste management structure be improved, using the systems of innovation approach, to enable innovation in mine waste management and minimise mine waste?

The literature indicated that the mine waste sector’s innovation framework can be analysed using the sectoral innovation system approach. The following key success factors, deduced from the literature, were used to examine the current mine waste management structure and identify areas of improvement: Legislative and policy support; Approach to innovation; Human resource capability; Research and development; Collaboration and interaction with other agents in the sector; Innovation funding; Innovation targets and Incentive to innovate.

Data for the study was collected through semi-structured interviews with questions formulated in a manner that seeks to extract rich and nuanced information about the structure of the mine waste management sector and its capability to innovate. Agents in the mine waste management sector were identified and contacted to request an interview. A model is presented to map out how the South African mine waste sector is structured. Following the systems of innovation approach, gaps in the structure were identified and suggestions on possible means of improvement provided.

Keywords: Sectoral innovation system, Capacity, Agents, Mine waste minimisation.
1. Introduction

1.1. Purpose of the study

The purpose of this study is to investigate how the South African mining sector can use the Systems of Innovation Approach to minimise mine waste and grow the sector’s contribution to the green economy. The study will examine the mining sector’s innovation capabilities and approach to mine waste minimisation. Using the Sectoral Innovation System approach, the study will identify ways in which mine waste minimisation can be improved.

The South African government aims to grow the waste sector’s contribution to the Green Economy by developing innovations that address waste minimisation. The New Growth Path identified the Green Economy as one of ten jobs drivers and aims to create 300 000 green jobs by 2020.

1.2. Context of the study

The mining sector remains one of the most important sectors to South Africa’s economy, accounting for 8% of the country’s GDP (StatsSA, 2016). The South African mining industry is the fifth largest in the world and accounts for half of the total merchandise exports (Chamber of Mines, 2012) and is one of the largest employers of semi-skilled labour in the Southern African region.

Mining is a process of extraction, beneficiation and processing of ore containing rock to produce minerals of value in the market (Oxfam America, 2006). A large amount of waste is generated in each phase of the mining process. In the beneficiation and processing phase waste is generated as the ore is chemically processed and refined to extract the mineral, which is a small fraction of the total ore. Waste is generated by mining operations include:

- Contaminated mine water;
- Overburden waste rock (in surface mining);
- Mine development rock (in underground mining);
- Tailings (Ore processing by-product);
Most of the waste generated by mining operations is disposed by landfill. Landfilling in this study refers to waste placed on surface of the earth as opposed to backfilling. It is a common occurrence in South Africa’s waste management practice. In 2011 an estimated 90.1% of all general and hazardous waste generated in the country was disposed to landfill according to the Department of Science and Technology (DST, 2014). According to the (DEA, 2012) and (EuroStat, 2013) South Africa is one of the top countries that relies heavily on disposal with a small percentage of total waste used for energy recovery and incineration as shown in Figure 1 below.

![Figure 1: Approaches to total waste management (adapted from DEA (2012) and EuroStat (2013))](image)

Globalisation, climate change, carbon economics and resource scarcity has caused a global paradigm shift in waste management. This paradigm shift requires that waste is no longer viewed as an unwanted by-product requiring disposal to landfill, but rather as a renewable resource, suitable for re-introduction back into the local and global economies (Perella, 2013). This shift in paradigm is reversing the waste hierarchy, moving away from disposal towards waste prevention, reuse, recycling and recovery as seen in Figure 2 below.
The transition into the green economy will require strategic planning, evidence gathering and investment in capability building and technology. Waste recycling, re-use and recover is one of the ten commitments outlined by the Department of Economic Development in the Green Accord (DED, 2011).

There has been an increase in waste legislation in South Africa since the promulgation of the National Environmental Management: Waste Act (2008). The intention of the legislation was to encourage safe waste management by landfilling and promoting alternatives to landfilling.

According to the National Waste Research, Development and Innovation Roadmap for South Africa (DST, 2014) developing and emerging countries, like South Africa, face many of the same waste management challenges as developed countries which were identified as:

- Lack of adequate infrastructure to deal with growing volumes of waste;
- Changing waste streams in terms of quantity and composition/complexity due to changing socio-economic conditions;
- Dominant means of waste management is disposal of waste to landfill, typified by open
dumps and open burning;

- Problematic waste streams being organic waste, packaging waste hazardous waste and, and construction and demolition waste.

- High tonnages of organic waste in the waste stream;

- Low levels of recycling, largely carried out by an informal sector; and

- Lack of adequate environmental legislation regulating waste management activities.

At the Waste Trends Workshop, held in February 2014 in Johannesburg, Durban and Cape Town, attended by waste management stakeholders, mineral waste was identified as one of the largest contributors but with little to no recycling as seen in Figure 3 below (DST, 2014).

![Figure 3: Plot of waste generation against recycling tonnages (DST, 2014)](image)

The waste streams were discussed in terms of the trend analysis, opportunity analysis and enablers to ensure success. The resolution of the workshop was to minimise the impact of mineral or mine waste on land and biodiversity by moving up the waste management hierarchy.

The delegates concluded that the recognition of value of mine waste, investment in research
and development, recognition of social and environmental importance, tax incentives, value proposition, legislation and compliance.

It can be concluded from the context given that mine waste management is a sector consisting of government, industry and research institutions. All sector stakeholders agree that reducing mine waste to landfill disposal will benefit the economy by creating a secondary sector in mine waste management as stipulated in the Green Accord. Technology, capability, relationships, infrastructure, government legislation and an innovative framework that could be managed is required to move mine waste up the waste hierarchy from disposal to reduction as shown in Figure 2.

1.3. Problem Statement

Main Problem

The main problem of this study is to investigate how the South African mining sector can minimise mine waste to landfill disposal and grow the sector’s contribution to the green economy.

Sub-Problem one

The first sub-problem is to examine the sector’s science and technology capability to reduce the reliance on waste to landfill disposal and how the stakeholders are organised and interact to enable innovation in mine waste management.

Sub-Problem two

The second sub-problem is to identify ways, using the systems of innovation approach, the current waste management structure can be improved to enable innovation in mine waste manage and minimise mine waste.

1.4. Delimitation of the Study

• The study will be restricted to the study of mine waste management as it relates to waste rock, ash and tailings and the stakeholders thereof. It will not look into the management of other types of mine waste like water and general waste.
• The study will be limited to the South African mining sector.
• The study will investigate the sector as a system and not venture into each stakeholder’s innovation capability.

1.5. Assumptions

• The study assumes that the South African government, mining companies, research institutions and other stakeholder want to minimise mine waste and reduce reliance on waste to landfill of mine waste.
• The mine waste sector is already working towards the goal of mine waste minimisation and reduction of waste to landfill.
• Mine waste will continue to be generated as long as minerals are mined in the country.

2. Literature review

The literature review will discuss and critically analyse the available literature on innovation and systems of innovation. It will also present some innovation principles that are applied in practice.

2.1 Innovation

Innovation is a concept as old as mankind, a phenomenon that has brought about our current day products, processes and ways of doing things. Jan Fagerberg proposes that innovation is something inherently “human” as demonstrated by the tendency to think about new and better ways of doing things and try them out in practice (Fagerberg, 2003).

Innovation seems to be a golden thread in the development of many disciplines, although it has not always been a discipline of research. Developments in Science and Economics have been attributed to other factors such as political ideology and market changes. Innovation studies outside the existing disciples started to emerge in the 1960s at prestigious universities (Fagerberg, 2003).
Innovation is driven by the ability to see connection, to spot opportunities and to take advantage of them (Tidd, 2013). It is important to note that an idea is considered innovative when it has been implemented and serves the market. Innovation begins at ideation but does not end there, it needs implementation. Innovation is not limited to the production of new products but happens in service provision and in developing new ways of doing existing things known as process innovation.

In organisations, the ability to innovate is represented by the ability to continuously transform knowledge and ideas into new products, processes and systems, to the benefit of both the organisation and its shareholders (Popa, 2010). Innovation has proven to be a source of competitive advantage for organisations especially in the technology space. The top revenue grossing companies today, like Apple and Google, can attribute their success to technological innovation.

The definition of innovation has evolved over the years and different authors phrase it differently. Joseph Schumpeter in 1930 defined innovation as introducing a new product or modifications brought to an existing product. As time went on the definition was brought to organisational management and defined as the degree to which specific new changes are implemented in an organisation (Mohr, 1969). Mohr’s definition was echoed by Dampour in 1991 when he described innovation as the development and adoption of new ideas by the firm.

Innovation can be defined as a process by which firms master and put into practice product designs and manufacturing processes that are new to them (Nelson, 1993). A broader definition of innovation was articulated by Slevin in 1991 and adapted by Lumpkin and Dess (1996) and more recently by Knox in (2002) as: The process that provides added value and a degree of novelty to the organisation, suppliers and customers, developing new procedures, solutions, products and services and new ways of marketing. It can be deduced from the definitions given that innovation is a process that encompasses all organisational elements, is new or novel in nature and adds value to the organisation, its shareholders and the end user or customer.

Freeman (1987) extended the definition of innovation at a macro level to factors outside of the organisation and the ecosystem in which the organisation exists: “The networks of institutions in the public and private sectors whose activities and interactions initiate, import and diffuse new technologies”. This is referred to as “Systems of Innovation” and will be examined further in the next section of this literature review.
There are four dimensions of Innovations which are described by Tidd and Bessant (2013) are shown in Figure 4 below. Innovation can further be positioned on a scale of “extremities” from incremental innovation where products, services and processes are improved to radical where a completely new product, service or process is implemented.

![Figure 4: 4 Ps of Innovation (Tidd and Bessant, 2013)](image)

**2.2 Systems of innovation**

The basic idea of analysing innovation as a system of national institutions can be attributed to Friedrich List in 1841. Freeman built further on List’s research in the early 1980s by noting that List’s concept of national systems of production considered a wide set of national institutions including those engaged in education and training as well as infrastructure such as networks for transportation of people and commodities (Freeman, 1995).

An innovation system can be defined as a group of private firms, public research institutions, and several of the facilitators of innovation, who in interaction promote the creation of one or a number of technological innovation [within a framework] institutions, which promote or
facilitate the diffusion or application of these technological innovations (Beije, 1988).

The Systems of Innovation (SI) approach is the most favoured framework for describing, analysing and understanding the process of innovation on various levels and how it can be influenced by policy measures (Schrempf, 2013).

SI approaches focus on innovation as an outcome with emphasis on the learning process of different stakeholders and how they learn from each other and exchange knowledge.

SI approaches can be characterized and compared by investigation on how they deal with the following six dimensions (Coenen and Diaz Lopez, 2010):

- System boundaries
- Actors and networks
- Institutions
- Knowledge
- Dynamics
- Policy implications

System boundaries is the main differentiator of the three levels of Systems of Innovations approach namely the National System of Innovation, Regional System of Innovation and Sectoral System of Innovation.

### 2.3 National innovation system

The idea of the national system of innovation was immanent in the work of several economists studying innovation in the 1980s (Lundvall, 2007). The work was focused on comparing technological policy and high technology institutions in the US with the policy and technological institutions of Japan and Europe specifically in the differences in management of innovation, work practices and engineering education.

In his 1987 book on innovation and innovation policy in Japan, Freeman brought the modern version of the full concept of National Innovation System (NIS) into literature (Freeman, 1987).
The NIS approach is rooted in theories of innovation, interactive learning and evolutionary economics (Lankhuizen, 2003). The belief with the NIS approach is that firms do not innovate in isolation but are constantly interacting with other actors/agents that form a system. The innovation outcome is therefore a result of these interactions within the system.

The NIS is often used as an analytical framework for studying the difference between countries concerning their production and innovation systems (Schrempef, 2013). In the overview of the NIS concept by Luc Soete (2012), five main elements of the concept emerge: Sources of Innovation, Intuitions, Interactive Learning, Interaction and Social Capital as seen in Figure 5 below.

![Figure 5: Elements of the National Systems of Innovation (Soete, 2012)](image)

2.4 **Sectoral innovation system**

The NIS and the Regional Innovation System (RIS) rely on a spatial dimension to define their boundaries. The Sectoral Innovation System (SIS) approaches, however, adopt certain technologies (spanning multiple sectors or the sector in which it used) as their system boundary (Schrempef, 2013). Dick Pavitt (1984) developed a taxonomy according to the sources of technology, the requirements of users and the appropriability regime:

- Supplier dominated sectors
- Scale-intensive large firms producing basic material and consumer durables
• Specialised suppliers

• Science-based ‘high-tech’ goods which rely on in-house and publicly funded research.

Similar to the NIS discussed above, knowledge generation and transfer between actors or agents is an important aspect of the SIS. Franco Malerba (2002) provided a workable definition of a sectoral system of innovation and production as: A set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products.

A model for a sectoral system and innovation was proposed by Eric Hansen and Ewald Rametsteiner (2006), adapted from Arnold and Kuhlmann (2001), where they mapped the framework of innovation in the global forest sector in order to identify gaps and research requirements within the sector. The model is shown in Figure 7 below.

![Figure 6: Sectoral system of innovation in the global forest sector (Hansen and Rametsteiner (2006), adopted from Arnold and Kuhlmann (2001))](image)

Malerba’s elements of SIS together with the model adapted by Hansen and Rametsteiner seem to be similar to those presented by Soete in the NIS approach in that knowledge and the interactions of agents or stakeholder is emphasised with the addition of basic technologies for SIS. This is consistent with Schrempt’s assertion that technology is the system boundary of the
2.5 Mine waste innovations

The mining sector has recognised the need for innovation in improving mining processes and waste management to minimise and re-use mine waste. The innovation imperative has been largely driven by stakeholder pressure as legislation becomes more stringent to encourage sustainability causing the disposal of mine waste to be a costly exercise.

At the company level, there is an increased understanding of the organizational culture (including attitudes, beliefs, values and norms that govern the behaviour of individuals and teams (Cummings et al. (2005)) and organizations are defining unique metrics for their innovation (changes in paradigms, processes or services that result in progress (McKeown, 2008). Increased communication, collaboration, experimentation and accountability within the industry have contributed to the evolution of innovation culture (Azam, 2008).

The Canada Mining Innovation Council is a national non-profit organization that coordinates and develops RDI programs in response to life of mine challenges defined by its industry members. The council seeks to address a number of cross-disciplinary and linked initiatives leading towards reducing the mining footprint (Kondos and Weatherell, (2014)). The council has recognised the need for inter-disciplinary and inter-sectoral interaction including government and research institutions in order to achieve their end goal of zero mine waste. This is a form of a system of innovation approach although a framework has not been proposed.

Some of the noteworthy innovation activities to come from the mining sector include innovations in mining process and engineered mine waste. Thickening is the process by which mine waste slurries are converted to non-segregating, paste-like materials that can be pumped (Robinsky, 1999). There has also been innovation in co-mixing waste streams like waste rock and tailings thereby reducing the total waste volume and surface area requirements for disposal (Azam, 2008)

Research questions one

Does the South African mine waste sector have the science and technology capability to reduce the reliance on waste to landfill disposal? If so, how are the stakeholders organised and interact to enable innovation in mine waste management?
**Proposition one**

Indication from the literature is that the innovation at company level is largely organised; driven by the need to comply with legislation, reduce waste management costs and gain competitive advantage. It is expected that the study will reveal that there is some interaction between a few players that are co-dependant in mine waste management and there is science and technology capability to innovate but that the sectoral innovation system between all key agents is informal and unstructured.

### 2.6 Sectoral innovation system in practice

The ICT sector has been one of the most innovative sectors in Europe of recent. In 2008, Wintjes and Dunnewijk conducted a case study of the sectoral innovation systems of the ICT Sector in Europe. The study identified the following factors as important in enhancing innovation in the ICT sector:

- Policy governing the ICT sector;
- Research;
- Human Resources
- European Integration; and
- Funding

Schade (2016) compared the innovation systems of different transport modes in Europe. He identified what he labelled an “innovation infrastructure” that provides incentive to innovate in the transport sector:

- Standards (Policy)
- Research and Development Support;
- IPR and Information;
- Venture Capital

The Mining Indaba and Monitor Deloitte study (2016) was conducted to engage mining
companies operating in Africa and understanding how they are innovating. The study identified innovation “building blocks” that enable innovation in the mining sector:

- A tailored approach built around clear definitions and approaches for the work to be done in generating innovations.
- A structured organisation to house the innovation strategy.
- Acquiring and nurturing appropriate resource competencies.
- Developing the right metrics and incentives with targets to guide performance.

Research question two

How can the current waste management structure be improved, using the systems of innovation approach, to enable innovation in mine waste management and minimise mine waste?

Proposition two

The available literature on the mine waste sector in South Africa indicates that there is a drive to formalise the innovation approach towards mine waste minimisation especially from a legislation and policy perspective. However, the informal and unstructured nature of the sector means that there are no innovation targets, limited collaboration and interaction among agents in the sector.

3. Research methodology

3.1 Research strategy

The strategy for collecting data required to answer the research questions underpinning this study was through a qualitative research and data collection methodology. A qualitative research methodology, through semi-structured interviews, investigating the innovation system of the mine waste sector in South Africa was followed. This methodology is similar to that followed by Ndlhovu (2016), where he used semi-structured interviews to explore the sectoral system of innovation and the technological capability building in the South African renewable energy sector.
Qualitative research is most commonly associated with certain schools which fall broadly within what is known as the interpretivist sociological tradition, particularly phenomenology (Schutz, 1976). Qualitative research is useful in obtaining rich, nuanced answers of people’s experience, giving the researcher a holistic perspective of the sought phenomenon.

3.2 Research design

The research approach in this study was exploratory and cross-sectional in style in the form of a face to face interview. Exploratory research examines the relevant factors in detail to arrive at an appropriate description of the reality of the existing situation (Brink, 1998).

A cross-sectional study looks at a sample of the population at a single point in time. Unlike the longitudinal alternative, which takes place over a long period and on more than one occasion, the cross-sectional study gathers data relating to a single period.

The exploratory approach is appropriate for this study because the first research question seeks to understand the system of innovation currently existing in the mine waste sector. There is very little published knowledge of the system of innovation in the mining sector, therefore an exploratory study provides new insights and understanding of how innovation comes about in the mine waste sector. The disadvantage of the cross-sectional approach, according to Thisted (2006) is that there is potential for selection bias when sampling and the generalizability is limited by the sampled population. Therefore, causality relationships will not be possible to identify.

3.3 Sample population

The sample population in this study comprised of 15 individuals in key institutions/firms in the mine waste sector, who were identified through purposive sampling. The literature review revealed the agents in the mine waste sector to be mining companies, research institutions, universities, consulting companies, advocacy groups and government.

3.4 Research instrument

The research instrument for this study was a semi-structured interview. According to Bernard (1988) a semi-structured interview is best used when the researcher will not get more than one
chance to interview someone. The following key success factors, deduced from the literature, were used to examine the current mine waste management structure and identify areas of improvement: Legislative and policy support; Approach to innovation; Human resource capability; Research and development; Collaboration and interaction with other agents in the sector; Innovation funding; Innovation targets and Incentive to innovate.

A list of open-ended questions was prepared (see Appendix A) before the scheduled interview and used as a guide during the interview.

Since the interview guide contained open-ended questions, the interviews were recorded and analysed in detail afterwards.

The advantage of a semi-structured interview is that the respondent will have freedom to express their views in their own terms (Cohen, 2006).

### 3.5 Data collection

A total of 15 semi-structured interviews were conducted in this study: 12 of these were core respondents and three additional interviews were done for triangulation of the collected data. The pre-arranged interviews were planned to last approximately an hour and were recorded for analysis. The interviewees were people who are knowledgeable about the technological developments in the mining industry but who are not necessarily directly involved in the mining industry. Supplementary data presented in the literature review was also used to inform the questions and explain some themes that came out of the interviews.

### 3.6 Data analysis and interpretation

Published Qualitative Data Analysis theory dates back to the 1960s. Grounded Theory Analysis by Glaser and Strauss (1967) is inductive and emerges from the data through a process of rigorous and structured analysis. The analysis included delineation of emergent concepts, conceptual coding, categorising concepts that lead to the identification of core theory.

The following steps were followed for analysing and interpreting the data collected (Lacey,
transcription: Interviews were recorded and transferred to text by way of notes.

- Organising the data: The data was organised into easily retrievable sections. The interviewees were given a code number as a means of identification during analysis.

- Familiarisation: Listening to recordings and making summaries

- Coding: Forming broader categories from the data and a list of codes that could contribute to each category.

- Themes: Identifying emergent concepts

3.7 Limitations of the study

Although using an interview as a research instrument is helpful in uncovering information that might be lost in a survey or questionnaire, it does have its limitations. Walford (2007) argues that interviews are not a sufficient form of data collection to study social and implies that they need to be supplemented by other forms of data collection. In an interview, there is also the possibility of getting large amounts of data that are not relevant in the study, making it difficult for the researcher to sieve through the data to find relevant themes. Robinson (2002) criticised interviews as being time consuming in both collecting the data and analysing it.

The following limitations to interviews as a research instrument were presented by Brown (2001):

- It is time consuming
- The study is at a small scale
- It is never 100% anonymous
- There is potential for subconscious bias from the researcher
• There is potential for inconsistencies.

The researcher endeavoured to overcome these limitations, to a reasonable extent, by being as concise as possible in the interviews, protecting the identity of respondents and referring to them in code and supplemented the data with observations of the respondent’s behaviours during the interview. It was also important to highlight any inconsistencies that are observed.

3.8 Validity and reliability

Validity and reliability issues serve as guarantees of the results of the participants’ performances (Alshenqeeti, 2014). There are two types of validity: Internal validity and external validity. Internal validity refers to the extent which the study answers the questions it is designed to answer and external validity the extent to which the findings can be generalised.

This study was designed to be able to examine the mine waste sector’s capability for innovation and therefore has internal validity. The study was limited to the south African mine waste sector and cannot be generalised outside of that boundary. Cohen et al. (2007) proposed the following factors be considered to minimise bias and increase validity:

• Attitude, views and prospects of the interviewer

• Tendency for the interviewer to see the interviewee on his/her own merits

• Tendency for the interviewer to seek answers to support their preconceived notions

• Misperceptions on the part of the interviewer with regard to what the interviewee is saying

• Misunderstanding on the part of the interviewee with regard to what is being asked.

Reliability refers to the extent to which a research instrument yields the same results on repeated trials (Alshnqeeiti, 2014). Interviews have a limited reliability because they are open to bias from the interviewer and misunderstanding from the interviewee. Cresswell (2009) argues that reliability is elusive during interviews and that no study reports actual reliability data.

The researcher endeavoured to increase the validity and reliability of the study by following
these guidelines from Alshnqeeti, 2014:

• Avoid asking leading questions
• Taking notes and not depending on the recordings
• Giving the interviewee a chance to sum up and clarify the points they have made.

4. Presentation of results

This section of the paper presents the results of the semi-structured interviews conducted during the data collection stage of the research. The agents that were interviewed include government departments and affiliates, consultants, small to medium and micro-sized enterprises (SMMEs), research institutions, a funding institution, a tailings construction and management company, a mining company. In total, 15 participants were interviewed from 14 different organisations. The participants interviewed were from the following organisations:

1. Department of Trade and Industry (DTI)
2. Department of Water and Sanitation (DWS)
3. Department of Science and Technology (DST)
4. Council for Scientific and Industrial Research (CSIR)
5. Water Research Commission (WRC)
6. University of the Witwatersrand (Wits)
7. MiWaTek
8. Green Iron Tech
9. Golder Associates Africa
10. Knight Piesold Consulting
11. Isithelo Consulting
12. Technology Innovation Agency (TIA)
13. Fraser Alexander
14. Exxaro

As previously stated, the problem statement will be investigated through two research questions:

First research question: Does the South African mine waste sector have the science and
technology capability to reduce the reliance on waste to landfill disposal? If so, how are the stakeholders organised and interact to enable innovation in mine waste management?

Second research question: How can the current waste management structure be improved, using the systems of innovation approach, to enable innovation in mine waste management and minimise mine waste?

4.1 Results pertaining to the structure and capability of the mine waste management sector

The responses presented below are pertinent to the first research questions which seeks to understand if and how the mine waste management sector is structured and whether it has adequate capability of innovating. The quality aspects and areas of improvement will not be discussed here but in the section that follows.

Legislative and policy support

The responses to the legislation and policy pertaining to the management of mine waste were varied among the respondents. There were mixed views regarding the clarity of the legislation and the knowledge of how to implement it. Some key themes that emerged from the questions pertaining to the legislation and policy were as follows:

- There is no clarity in the legislation and policy of managing mine waste, the pieces of legislation from different government departments are contradictory.
- Coherence of legislation is absent.
- The legislation is well written and clear but there is a desire by mine waste generators to pursue ambiguity.
- High level requirements of the legislation relating to the waste management hierarchy is not clear but legislation and policy relating to the protection of water resources and the environment is clear.
- The legislation is clear through the mandatory codes of practise.
- There is clarity in the legislation but a lack of enforcement from the government.
- Legislation and policy pertaining to mine waste needs to be updated.

Nine out of the 15 respondents perceived the legislation and policy to be clear. Two of the
respondents who do not work directly with the legislation were not aware of its existence and the rest of the respondents did not think the legislation and policy were clear. Implementation of policy seems to be applied only to meet the objectives of obtaining operating licenses from the different government departments.

Approach to innovation

All the participants interviewed claimed to have a structured approach to innovation but very few were able to explain their structured approach to innovation. Some of the themes emerging from the responses were as follows:

- The governmental research and funding institutions (CSIR, WRC and TIA) said that it is their mandate to be innovative. A representative from the WRC said the following: ‘Our whole business is about encouraging innovation. In addition to the funding system and the research branch, we have a different branch called Impact and Innovation.’
- Continuous learning and research in the area of mine waste was identified as one of the ways in which innovation is encouraged.
- The research institutions and the university pursue research in knowledge gaps identified by industry (mostly from mining companies and consultants who design mine waste facilities).
- The ability to be continuously innovating is motivated by the need to have a competitive advantage by the SMMEs. A representative from Miwatek, a SMME developing technologies to clean acid mine drainage, when asked if his organisation encourages innovation said: ‘We do, we are obviously a technology company and a big part of our effort goes into developing our competitive advantage which is basically our technology’
- Co-disposal of different waste streams and dewatered waste are significant innovations in the mine waste management sector.
- Flexibility, hard work and having the right formal skills were prominent key elements that enable innovation as identified by the respondents.

Innovation is an important component in the work of consultants and SMMEs in maintaining their competitive advantage while research institutions bridge the knowledge gap that is a significant element in bringing about innovation in the sector. Only one out of the 15 participants (Exxaro), however, said that innovation is a drive from the top management of the
company.

**Human resource capability**

The respondents listed typical technical skills they needed for each of their organisations as well as personal attributes of people. The following responses were noted:

- The research institutions (CSIR and WRC) need people who understand research and people who have lead research groups as well as a combination of technical skills including engineers, environmental scientists, financial scientists, political scientists, anthropologists, journalists, geographers, environmental lawyers and people with communication skills.
- The DST does not need a lot of specialist technical skills, the departments focusing on mine waste management oversees the research and funding bodies that report to it.
- The DTI has environmentalists and economists within the department but also has a multidisciplinary advisory committee that it draws a lot of skills from.
- Of the government departments interviewed, only the DWS seems to be using a lot of the technical specialist skills like engineering geologists, geohydrologists and hydrologists but also mentioned that the department employs people with a passionate interest in contributing to value engineering. The respondent from DWS said the following:

  ‘I think that the skills that are required are more than knowledge, it’s really an attitude and an aptitude. The individual that’s chosen needs to have more than just a degree in the appropriate sciences or engineering’

- SMMEs generally have “lean” company structures with not more than 10 engineering and science specialists while outsourcing the complementary skills needed in their businesses. They also mentioned the need for a balance between technical skill and “soft” skill or interpersonal skills.
- Strong engineering specialist skills are required a lot by the consultants who design mine waste facilities. They need people with a good understanding of the engineering theory and design like tailings engineers, geotechnical engineers, geochemists and hydrogeologists. This group of agents also identified emotional intelligence skills as key to contributing meaningfully to the waste management sector. One respondent said the following:

  ‘Good management and freedom to allow people to look at alternatives is one skill you
could [use], understanding what people’s interests are and allowing that to develop.’

- A respondent from Fraser Alexander said that it’s important to have people that understand the mining process and that the support and encouragement of management is important when these different skills interact.
- One respondent from a mining company said that research and development skills are needed to contribute meaningfully to mine waste management.

Many skills from different disciplines of science, engineering, economics, law and finance are required in the mine waste management sector. It was noted that most of the respondents (13 out of the 15 interviewed) also identified interpersonal and people management skills as being important too.

**Research and development**

Respondents were asked about the research and development taking place in their organisations and in the sector. The following responses were given:

- There is not enough research in the area of mine waste management in research institutions.
- The research institution’s key mandate is to provide research evidence for policy drafting and evidencing dialogue.
- Research in mine waste scored low in South Africa’s capability mapping study report.
- Technology diffusion among agents in the system is very poor owing to the “silo mentality” of the different organisations.
- Research is more focussed in the area of mine waste water treatment than on mine solid waste management because it is perceived as a much bigger problem.
- Shareholders of the different organisations are more interested in the “bottom line” than in protecting the environment.
- The DST and the DWS contribute to creating new knowledge in the sector by creating incentivising conditions for knowledge generation and funding research at various institutions (universities, CSIR, WRC and the National Research Fund).
- The SMMEs seem to be experiencing a lot of technology diffusion albeit limited because of the need to protect intellectual property.
- Most of the learning and technology diffusion in the sector happens through conferences and the publishing of academic papers.
• Consultants in the sector share knowledge among each other through the South African Institute of Civil Engineers.

• Learning within the organisation is largely a personal initiative driven by individuals rather than the organisations. One of the respondents put it this way:

‘A body like SAICE would obviously produce these magazines and there’s conferences but if you don’t take a personal interest in picking up that new technology or picking up that new learning you can get left behind, so it’s very personal driven’

• Over the past 15 years there has been significant research contributions in dewatered tailings, effective closure mechanisms, treatment of acid mine drainage, underground gasification of coal seams and liner systems for the protection of ground water.

• The knowledge in the sector lies with a few individuals who are regarded as experts in the sector rather than organisational wide.

It is important to note that all 15 of the participants said that there is not enough research done in the area of mine waste management and particularly in mine waste reduction. There are pockets of learning and technology diffusion in the sector among similar organisations (SMME’s, research institutions and consultants) and most of the cross-learning happens through conferences and the publishing of academic papers as a result of individual effort

**Collaboration and interaction**

In this set of questions, the respondents were asked if there are any platforms of interaction available for interaction with other stakeholders in the mine waste sector and if any developments or advancements in innovation arose from this interaction. 10 out of the 15 respondents said there is plenty of interaction and collaboration within the sector. The themes emerging from their answers were as follows:

• Research institutions and government departments collaborate and interact extensively with other agents in the sector.

• There is limited interaction among consultants who design mine waste facilities. These organisations mainly interact with specialist individuals rather than with organisations.

• There is significant collaboration on a project basis between research institutions, government departments and SMMEs.

• All the agents interact and collaborate with institutions of higher education.

• Platforms available for collaboration include mutually beneficial projects, conferences,
industry committees, workshops, The Institute of Waste Management, Symbiosis (a data base created to share information) and sector associations.

- One consultant said there are platforms available for information sharing but not for collaboration.
- The main factors that restrict collaboration among consultants is that they require their clients to pay for any interaction and they use their knowledge as competitive advantage therefore they keep their work “ring-fenced” as one respondent said. Another consultant, when asked why he thinks consultants in the sector seem to be so self-sufficient, said:
  ‘I think they want sole propriety of what they develop and they want to develop it themselves rather than giving it away and it becoming public’
- A significant collaborative project in the sector was the development of the RDI roadmap on waste led by the CSIR and the DST. Many stakeholders in the general waste sector, including mine waste, were invited to give input into the roadmap.

Collaboration and interaction within the mine waste sector is dominant within research institutions and government departments and quite limited between agents in the private sector, especially between consultants. The institutions of higher education are key players within the sector because all organisations that participated in the study interact with them. The platforms for interaction and collaboration are quite formal in the form of memoranda of understanding, conferences and formal bodies.

**Innovation funding**

Participants of the study were asked how they would go about funding innovations at company level and if there are government funding institutions willing to fund innovation project in mine waste management specifically. The themes for innovation funding were as follows:

- The CSIR funds a small amount of research internally but the majority of the funding for research is sourced from funding institutions like the National Research Fund. Similarly, Wits University would put together proposals and approach research funding institutions for funding.
- The WRC outsources their research and would fund research that is in the proof of concept stage.
- The government departments do no fund research and development internally but
would use their agencies like the TIA to fund innovation projects from the public.

- The SMMEs in the sector find it very difficult to get funding to get their innovations to market. The technology developed in the sector is capital intensive and government funding agencies like the TIA has a cap on how much they can spend on getting a certain technology to market. One of the SMMEs interviewed had to fund some of their innovations internally.
- Commercial banks are risk averse and are reluctant to fund innovations within the sector because they are high risk and require a lot of capital.
- Consults fund their innovations in collaboration with the mining companies who are their clients or the mine waste facility operators provided the innovation projects are not capital intensive.
- The TIA utilises three financial instruments in their contracts with applicants namely loans, equity and conditional grants.
- The mine waste facility operators and mines fund innovation internally, they rarely approach funding institutions for innovation funding.
- The funding institutions available for funding innovation in the sector are the National Research Fund, the WRC, the Industrial Development Corporation, the Green Fund, the Development Bank of South Africa, TIA, Trans-Caledon Tunnel Authority and the Council for Geoscience.

All organisations that looked for funding (eight out of 14) outside their organisations approach government agencies for funding. Those that don’t seek funding spend only a small amount on new innovation projects which is limited by the company’s economic cycle. Private funding institutions or companies are rarely asked to fund innovations in this sector.

**Innovation targets**

Participants were asked about any government targets relating to minimisation of mine waste and targets from within their organisations. The responses were as follows:

- There are no known government target regarding minimisation of mine waste.
- Some of the respondents (research institutions and government departments) were aware of waste targets set out in the Research, Development and Innovation (RDI) roadmap, an initiative of the DST, but these are not adopted government policies.
- There are regulatory reviews which are set to conclude in March 2018 that will set up
targets for the different waste producing sectors in South Africa.

- The participants from the private sector were aware of the waste hierarchy and the desire by government to move waste up the hierarchy but not aware of any government targets or the RDI roadmap.

None of the organisations interviewed had any waste minimisation targets of their own, only organisation growth and revenue targets.

*Incentive to innovate*

The biggest incentive to innovate within the sector is the tax rebate for investment in research and development set up by the DST. The many funding agencies by government to fund technology innovation are also seen as an incentive by the SMMEs and research institutions. Maintaining the company’s competitive advantage is a significant driver of innovation in the private sector, especially SMMEs who are investing a lot of money in developing beneficiation technology in the sector. The mining, operating and consulting companies interviewed do not think there is any incentive to innovate in mine waste management for their organisation.

The majority of the participants think that the enforcement of already existing government legislation on mine waste management and a clearer government policy would go a long way in incentivising innovation. Some of the incentives suggested by the participants were easier access to funding, appealing to the social and environmental conscience of organisations and financial incentives of economic value.

### 4.2 Results pertaining to the value characteristics of the sectoral system of innovation in the mine waste management sector

The responses presented below are those relating to the quality and value characteristics of the mine waste management system of innovation and therefore answer the second research question as stated above. The questions were formulated such that the responses could reveal the inadequacies, if any, and areas of improvement in each of the success factors for a sectoral system of innovation.

*Legislative and policy support*

Many of the respondents noted the contradictory nature of the legislation and policy around
mine waste, some pointing out that it is difficult to implement legislation pertaining to mine waste management cost effectively. A significant theme of a “push back” or “tug of war” between government departments and mine waste generators because of the cost implications of the legislation emerged from some of the respondents. The following responses relating to the inadequacies of the legislation and policy were noted:

- There are conflicting pieces of legislation from different government departments. This was raised most vehemently by an employee of the WRC who said: ‘The DMR and the DEA have different guidance regarding the management of tailings. Department of Water and Sanitation are responsible for things like water use licenses which not only include extraction of raw water but includes the disposal of impacted water or waste water yet the Department of Mineral Resources also makes a claim that it is the only department you need to go to for permission to mine and that includes the water use side... In the instances where there is the absence of direct conflict, there is a lack of clarity.’
- Mining companies are reluctant to comply with the legislation because of the cost implications.
- There is no consistent application of legislation.
- DEA and DMR classification of mine waste is not the same.
- Research that informs policy is not written in a manner that policy makers can easily understand.
- Legislation and policy is not implement with the aim of sustainable development. This was perhaps well articulated by a respondent from the DWS who said: ‘They [mining companies] are pursuing a piece of legislation to get a licence to move ahead with an activity and not giving due diligence to sustainable development, looking at their own economic welfare and that’s where I think the biggest failure is.’

What became evident during the interviews is that mine waste legislation and policy in South Africa is fairly new and the implementation thereof is not quite clear to those that need to implement it. There are three departments that have legislation and policy relating to mine waste management namely the DMR, DEA and DWS. Five out of the 15 respondents (including those from government departments) said that the pieces of legislation from each of these government departments are conflicting or contradictory. The legislation around mine waste management has a significant cost to the mining companies and as such, they are
reluctant to comply with the regulation in full.

**Approach to innovation**

All of the respondents said they do encourage innovation but very few had a formal structure in their approach to innovation. Some of the responses relating to the characteristics of the approach to innovation were:

- The government departments are fundamental in setting up a conducive environment for innovation, particularly among research institutions and government funding institutions.
- An innovation drive is not uniform among the bigger organisations but there are “pockets of excellence” as described by a respondent from DWS.
- The drive for profitability impedes the pursuit of innovation by the mining companies as described by those in government departments working with mining companies.
- The approach to innovation is seen, in most of the answers, in the innovative projects implemented rather than at organisational level.
- Majority of the respondents listed abstract elements like passion, hard work and resilience as key to being innovation and not necessarily measurable attributes like collaboration, funding and research and development.
- The mining company that participated, together with the SMMEs, had a proactive approach to innovation.

There seems to be a high awareness for innovation among the participants but a structured approach is lacking in many of the organisations. Apart from the funding agencies, the government departments and the research institutions, there is very little evidence of proactive collaboration with other agents in the system in projects aimed at producing innovations.

**Human resource capability**

Nine out of the 15 respondents said that they believe that they were adequately resourced but added that they could always do with more skills. Some of the themes that emerged were as follows:

- The level of research capability in mine waste management is still being developed because it is a relatively young research discipline in South Africa.
• Mining waste is a weak area of research because the need for research in this area has not moved to the national agenda of innovation.
• There are not enough people with the required research skills in this area of research because of the limited funding for research in general in the country.
• There are enough graduates coming from the universities but there is a big gap in skills in the mid-range level of experience in the sector. This was attributed to the many specialists who were trained in South Africa but left to seek better opportunities in other countries.
• One of the SMMEs interviewed said that it is not difficult to find the right people with the right skill but difficult to find individuals who are the right fit for the company.
• Funding/budgetary constraints was a significant emerging theme for the inadequacy in skills within the organisation as opposed to a limitation in the skills pool of the country. A respondent from TIA said:
  ‘I think we could do with more [skills], like I said with us currently in our team we cannot afford a mining engineer in our team. If we were to have a full skill set we would have liked to have like, for mining in particular, to have a geologist, a mining engineer, a processing engineer, an environmentalist and so forth and so on, but we manage with what we have and that’s a budgetary constraint’
• The mining industry hasn’t been growing economically over the past few years and that has caused many organisations to reduce their staff complement.

South African tertiary institutions seem to be producing enough skills needed to contribute meaningfully in mine waste management but the lack of funding for research and budgetary constraints of the individual organisations doesn’t allow them to employ people trained in these skills. Two of the 15 respondents said they don’t have enough skills required within their organisations and cited funding/budget as the primary constraint. There are not enough researchers in the area of mine waste management because the area of research is fairly new to the industry and the country.

Research and development

The quality elements of the research and development that happens in the sector was drawn from the reasons provided by the respondents for their answers in the previous section. There were varying reasons for why none of the respondents thought there wasn’t enough research and development in mine waste management. These were grouped into the following themes:
• The broader waste sector is risk averse when it comes to funding technology and is slow to adopt new knowledge because of the “I don’t want to be first syndrome” as one respondent phrased it.

• There is a tension between creation of jobs and technological advancement in the sector. A respondent from the CSIR said:

‘I think that the challenge for South Africa, and I know that the tide is changing, is that the mining sector in South Africa has always been a labour intensive section and the result is that you [gotta] get people underground which means you have to be working in spaces that are conducive for people and for the height of people and for ergonomics and for working conditions and all of that. The result is that you are taking out a lot of waste material unnecessarily. If you look at some of the high tech in mining that’s happening around the world where you can literally go in and kind of mine out centimetres of seam, it means reducing the amount of waste material’

• Diffusion of technology and learning is low compared to other countries because there is a gap in the funding of the innovation system. There are no funding agencies available for development between the stage of producing the first prototype and the stage when there is a viable business case.

• Other types of support like mentorship, market research and building a business case are lacking.

• In conventional mining and processing there isn’t scope to reduce mine waste.

• The country is not geared for rapid diffusion of technologies because of an inadequate venture capital funding ecosystem.

• The extent of environmental conservation thinking and teaching undergraduate and postgraduate level is inadequate.

• Regulation and legislation rely on attributes that are not part of mainstream academia (the example given was that the regulation requires a liner system for mine waste facilities yet it is not taught at university level).

• Technology diffusion is hampered by the lax enforcement of legislation.

• The link between government and research institutions, which serve to provide evidence for policy, is weak at best.

• The current political climate (January 2018) is not conducive to technology diffusion.

• Government representatives don’t attend enough conferences and courses within the sector resulting in government not understanding or being behind the latest
developments in the sector.

- Dominant agents in the sector, like the mining companies, have sometimes blocked new technologies entering the market to protect their competitive advantage (uncompetitive behaviour).

There are many underlying reasons for a lack of technology diffusion within the sector many of which relate lack of funding for research and development for both in-house research within organisations and from government funding agencies. There is also evidence of a disconnect between government, research institutions and mine waste practitioners.

**Collaboration and interaction**

There were obvious strong and weak links of interaction and collaboration between the different organisations interviewed for the study. The strong and weak collaborative relationships between categories of organisations are mapped.

- **Government departments:** Strong collaboration and interaction with universities (University of Cape Town, Stellenbosch University, University of Pretoria, University of Kwa-Zulu Natal, North West University, Wits University), other government departments in the mining and waste cluster, WRC, CSIR and mining companies. The weak interactions are with the Chamber of Mines and SMMEs.
- **Research institutions:** Strong collaborations with the mining companies, government departments, all the universities listed above, TIA, National Research Fund, Col-tec, Eskom and Sasol. The research institutions have weak interactions with consultants in the sector.
- **Wits University:** Strong collaborations with interaction with University of Pretoria, mining companies, consultants, Fraser Alexander. Wits has weak interactions with University of Cape Town and Stellenbosh University in the area of mine waste and no interaction with the CSIR or government departments.
- **SMMEs:** Small to medium enterprises have strong interactions and collaboration with the universities (mainly Wits University, University of Johannesburg and University of Pretoria), Mintek, the Swedish Research Institute, WRC, TIA and other funding organisations and the mining companies. The weak links of interaction are with government departments.
- **Consultants:** The strongest collaborative partner the consultants have are the universities
(mainly the University of Pretoria and Wits University), The South African Institute of Civil Engineers and the mining companies who are their clients. They have very weak interactions with research institutions, government departments and the Chamber of Mines.

- Technology Innovation Agency: Strong collaboration with government departments (especially DST who they report to), SMMEs, CSIR, University of Pretoria and Wits Universities. They have a weak collaborative and interactive link with University of Cape Town and the Mine Health and Safety Council.

- Exxaro: Strong collaboration with the Chamber of Mines, consultants and research institutions but very weak interactions with universities.

The biggest collaborator in the mine waste management sector seems to be the government departments followed by the research institutions and universities. Consultants collaborate the least within the sector.

**Innovation funding**

The respondents, in their answers, also highlighted some aspects of innovation funding in the sector that worked really well and some challenges in funding faced by the sector. These can be summarised as:

- Government institutions are willing to fund innovations in the sector from concept stage through to a point where the innovations reach the market.
- It is relatively easy to fund concept proofing research and development both from within the organisation and from government funding agencies.
- There is, however, a gap in the funding cycle as innovation projects move from concept to full scale development. The WRC and the NRF, for instance, would fund concept proofing research and the IDC funds market ready innovations. The TIA is meant to fund the stage between concept and market introduction, however, they have a funding cap of R50 million and some innovation projects can cost more than that in the full scale development stage. One of the participants said: ‘I think that’s a key challenge in South Africa at the moment. The NRF tends to fund early stage research... TIA was meant to kind of fund the innovation chasm and industry would be funding the near market ready innovations... we are seeing challenges across all of that’
- There isn’t a “one stop shop” where an innovation can be development and funded from
concept to market ready. SMMEs have to approach different institutions for every stage of development.

- The turnaround time to get approval for funding from government agencies takes a very long time. One of the SMME respondents said it took his company two years to get a response from a government funding agency, by which time he had already sourced internal funding for the project.

Although funding is available from government agencies to fund innovation projects in the mine waste management sector, it is difficult to navigate the process and it takes a long time to get the funding if funding is granted. There exists a gap in the funding process between proving the research and getting the innovation to market.

**Innovation targets**

The quality aspects of relating to innovation targets within the sector were:

- There are comprehensive targets for general waste management but not for mining waste. This is partly because the general waste situation is quite urgent and because mine waste has only recently over the last decade been classified as waste. Mine has been classified as residue before that and excluded in the waste management planning dialogues.

- Some of the general waste targets including reducing waste to landfill by 60% by the year 2025 and 90% by 2030. Interestingly, the respondent who gave these figures does not think the targets will be met.

- The research institutions were of the view that targets need to be set higher up the value chain, like mining techniques and processing methods, rather than at the mine waste management stage.

**Incentive to innovate**

As mentioned earlier, a significant incentive to innovate within the sector is the 150% tax rebate on research and development spend, an initiative of the DST. One of the SMMEs interviewed, however, said the process to try and get this rebate is full of bureaucracy and very onerous. The representative from the DST corroborated this by saying there is a two-year backlog of payment for these tax rebates and are looking at restructuring the process.
Accessibility to funding emerged as a prominent disincentive innovation within the sector together with the lax implementation of legislation on the part of government.

### 4.3 Summary of results

The majority of the participants were aware of legislation and policy governing mine waste in South Africa, however, there were mixed views regarding the clarity of the legislation and the knowledge of how to implement it. The approach to innovation is structured differently among the different organisations and many private sector firms perceive innovation as a competitive advantage for the firm. Skills from different disciplines of science, engineering, economics, law and finance are required for innovation advancement within the sector as well as interpersonal and people management skills.

All participants interviewed agreed that there isn’t enough research and development in the mine waste management sector. There is collaboration and interaction among the agents in the system, most of which are of a formal nature like conferences and formal committees/bodies. Innovation funding is largely sourced from government funding institutions although it is difficult to apply for and isn’t enough to fund the capital intensive technology used in the sector. Some of the participants were aware of general waste targets set by the government but did not know of any government targets regarding the minimisation of mine waste apart from the RDI roadmap by the DST and none of them had any waste minimisation targets of their own within their organisations. There is a tax rebate incentive for research and development within the sector by the DST but it is a very onerous process to follow and a prominent disincentive to innovate is the inaccessibility to adequate funding.

### 5. Discussion of the results

This section will provide an in-depth analysis of the results presented. The collected data will be compared and contrasted with the literature and the South African mine waste sector structured will be mapped out to see if there is technological capability to reduce reliance on waste to landfill disposal. This will answer the first research question. Following the systems innovation approach, gaps in the structure will be identified and suggestions on possible means of improvement provided to enable innovation in the mine waste management sector aimed at reducing mine waste. This will answer the second research question.

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The model by Hansen and Rametsteiner (2006) for their research of the innovation system in the global forest sector, presented in the literature review, will be adapted and used as a basis for analysis and mapping the mine waste management sectoral system of innovation. The model, populated with the organisations interviewed in this research, is shown in Figure 8 below. The linkages between the agents in the system are excluded in the figure and will be shown after the analysis of the results.

**Figure 7: Proposed sectoral innovation system model (adapted from Hansen and Rametsteiner (2006) by author)**

### 5.1 Legislative and policy support

The legislative environment in which a system of innovation operates is very important because it can accelerate the innovation process or hinder it. The government is responsible for creating the framework conditions for the system of innovation by drafting policy that will enable the system to innovate. This includes the financial environment, taxation and incentives, propensity to innovation and entrepreneurship and mobility as illustrated in the proposed model above.

Korres (2012) argues that it is at policy level at which the national system exerts huge influence over regional and sectoral systems. Governments have the duty of not only considering the
consequences of policy at a national level but also at a regional and sectoral level. Schrempf, Kaplan and Shroeder (2013) state that a major contribution to the innovation system debates is the idea that there is no single one-size-fits-all policy. Policy instruments need to be context specific considering both the national, regional and sectoral circumstances. Good policy implementation in an innovation system can help overcome anti-competitive behaviour by agents in the system, they can address skills shortages and incentivise businesses to take more innovative risk.

Within the mining sector of South Africa, the DMR is supposed to be the lead agent in providing legislation and policy relating to the management of mine waste, apart from granting mining licences. In practice, however, it seems that DWS, DST and DEA also have significant influence in policy governing the management of mine waste. DWS has policy focused on protecting surface and ground water resources in line with the National Water Act, 1998. The DEA is introducing policy instruments that aim at protecting the fauna, flora and air quality of the areas where there is mining activity, requiring clear environmental management plans from the mining companies. Similarly, the DST is introducing policies aimed at research and development. It was evident, from the data collected, that there is some disconnect between all these government departments as their policies seem to contradict each other at times. The policies have also been criticised as unclear and lacking coherence.

The lack of enforcement of the regulations and policies have also led to cases where mines have a license to operate but not the necessary plans in place to protect the water resources and the environment. It was also discovered that the high cost of complying with the regulation has led to the reluctance of mining companies to comply with legislation.

Formal legislative and policy framework structures exist within the South African mine waste management sector and corresponds to Korres’ assertion above that mining, environmental and water use policy at a national level exerts a huge influence over the sectoral level. The lack of clarity and poor enforcement are evidence of legislation that is not context specific as discussed by Schrempf (2013) and his colleagues. This could be delaying or impeding innovation within the sector.

5.2 Approach to innovation

Innovation is an organisational systematic process started at ideation through to selection and
finally implementation. It is a process that is not confined to new products and services as stated by Knox (2002) who defines it as the process that provides added value and a degree of novelty to the organisation, suppliers and customers, developing new procedures, solutions, products and services and new ways of marketing. The innovation process needs to be managed at all business function of the organisational. Goffin and Mitchell (2016) described how innovation cuts across functional boundaries and organisational functional areas like research and development; industrial design, marketing; sales; operations; finance and accounting; human resource management; senior management and outside resources like suppliers should all be part of an innovation strategy at organisational level.

The participants from the research cluster and the TIA regarded innovation as their core mandate but it was difficult to identify any structured systematic approach to innovation within their organisations apart from working on innovative research and development projects. Innovation in the consulting cluster, companies which have contributed significantly to innovation in the sector, mostly happens haphazardly on the job as employees carry out projects for the mining companies, one participant described this as systemic innovation. The mining company interviewed was the only organisation to mention a systematic approach or “drive” to innovation from senior managers across business functions as Goffin and Mitchell stated in their description of innovation management.

It was the SMMEs interviewed that had very high regard and motivation for continuous innovation not only in the products they produce and services they provide, but also in their business models. They understand that keeping their technologies current and relevant to the sector by global standards is their competitive advantage. The government departments interviewed had quite a narrow view of innovation limited to research, development, products and services, with a few ‘pockets of excellence’ emerging at times.

A significant innovative development that seems to have emerged from a collaboration between a few agents in the system was the co-disposal of different waste streams. This was mentioned by the consultants, the mining company and the research institutions. It was interesting to note that the majority of the respondents listed some abstract elements like passion, hard work and resilience as key to innovation but not any measurable attributes found in the literature like research and development, funding and collaboration.

Innovation initiatives and projects like research and development are low priority in profit
generating organisations like the mining company and the consultants because they get cut from the budget when the economic environment is not favourable, which is not surprising.

In general, it was found that the approach to innovation is not systematic at the organisational level in the majority of the agents in the mine waste innovation system, with the exception of the mining company and the SMMEs interviewed. There isn’t a tailored approach to innovation in the form or a strategy, innovation portfolio management and innovation process management. Innovation management at a strategic level seems to be missing in many of the organisations interviewed resulting in innovation emerging by chance within the sector rather than through a strategic process with value adding returns.

5.3 Human resource capacity

Innovation relies heavily on the skills and knowledge of people who carry out the innovation process. The capability of the people in any innovation system cannot be overstated. Agents within a system of innovation are characterised by specific learning processes, competencies, beliefs, objectives, organisational structures and behaviours (Malerba, 2002). Marleba further states that the knowledge base of innovative and production activities differs across sectors and greatly affect the innovative activities, the organisation and the behaviour of firms and other agents within the sector.

It is to this end that the link between knowledge producing system (universities and research institutions) and the production system (mining companies, consultants and SMMEs) of the mine waste sector should be aligned. Accessibility to human resource capacity and skill should be available for the agents in the system to continue to innovate. The Mining Indaba and Monitor Deloitte research into innovation in the broader mining sector found that organisations that don’t have a reputation of being innovators struggle to attract and retain talent with the distinct skills and propensity to innovate.

The skills required in the mine waste management sector are diverse across disciplines of specialisation. Engineering was identified as a core skill required within the sector in mining companies, SMMEs, consultants, research institutions and government departments. Other skills include environmental scientists and lawyers, financial scientists, geographers and people with strong research capability and communication skills. There doesn’t seem to be a shortage of skills in the skill pool produced by universities and institutions of higher learning, which is
encouraging, but there is a gap in the mid-range (10 to 15 years) experience level in some organisations.

The two main constraints to getting to a state of capacity adequacy in skills, according to the participants of the study, is a limited budget to pay for the resources and organisational fit on the part of the SMMEs. There is also training within organisations available in most of the participating organisations to get the skills level of graduates to a stage where they can contribute meaningfully.

It can thus be concluded that the mine waste sector requires a range of skills, including interpersonal skills, to contribute meaningfully to the sector. The skills pool from institutions of higher educations is adequate to serve the sector and has a positive effect on the capability of the sector to innovate as Malerba (2002) stated, although the low economic growth of the country has decreased the uptake of skills from these institutions. The link between the knowledge producing system and the production system is strong in terms of capability supply.

5.4 Research and development

Research and development is one of the most essential component of a system of innovation in both the national and sectoral level. Research and development is a crucial source of new knowledge for a system of innovation. Wintjes, in his 2008 study of innovation in the ICT sector in Europe, stated that a high level of innovation in the sector is strongly associated with two dimensions of the knowledge base of the economy: R&D intensity and the level of skills.

Wintjes assertions are supported by many authors of the systems of innovation approach including Schade (2016) who includes research and development as one of his four “innovation infrastructure” pillars and Cooke and Piccaluga (2003) who included a “knowledge generation subsystem” in their regional innovation system. The Canada Mining Innovation Council also relies heavily on research and development to address initiatives of bringing about innovation in the sector.

Research and development is, of course, not a foreign concept in the South African mine waste sector. A lot of innovations currently being employed within the sector like paste technology and co-disposal of waste was a direct result of research and development.

It was found that research in the area of mine water treatment is significantly more than research
in mine solid waste because mine water contamination is seen as a much bigger problem than solid mine waste. Government relies on research provided by research institutions like the CSIR and the WRC to evidence policy drafting and dialogue. Although research is recognised as important in informing policy, research in solid mine waste to landfill has not been given priority to inform legislation around disposal of mine waste.

Technology diffusion in the sector happens mostly through conferences and collaboration on specific projects. The SMMEs said that technology diffusion is hampered by the need to protect intellectual property. It seems as though a lot of knowledge pertaining to solid mine waste management lies with individuals in the sector rather than organisations, raising questions about knowledge transfer within the sector. Some of the respondents mentioned that the lack of funding for technologies in the stages between first prototype and viable business case contributes to the low level of technology diffusion.

It can be concluded that research and development in the area of mine waste reduction is very low in general. This could be the main reason why solid mine waste management technology has been slow to emerge over the last couple of years in the sector as stated by Wintjes. There is a lack of funding for the research needed to advance innovation in mine waste reduction from within organisations and from funding institutions. Intensifying the level of research and development coupled with the skills available within the sector could accelerate innovation in the sector. Mine waste reduction needs to be prioritised and form part of the national waste agenda.

5.5 Collaboration and interaction

Collaboration and interaction between agents of a system of innovation is the main conduit for learning from other stakeholders and for technology diffusion. Doloreux and Parto (2005) list the interaction between agents of the innovation system in relation to the exchange of knowledge as one of the three main dimensions. Continuous learning of each stakeholder from the other as they interact allows the system to adapt to changes according to Soete (2012).

Collaboration and interaction within the mine waste sector is dominant between research institutions and government departments and limited between agents in the private sector, especially between consultants. This can be attributed to the requirement by consultants for the mining companies to pay for any project specific collaboration opportunity that may arise. The
Platforms for collaboration are mainly formal within the sector through mutually beneficial projects, conferences, industry committees and workshops. The biggest collaboration project for the sector was the development of the RDI roadmap on waste, although the focus of solid mine waste was minimal. A central point of collaboration lies within universities because all of the organisations that participated in the study collaborate and have collaborated with universities in one form or another. This is an indication of a strong social capital the universities in the country have. Soete (2012) defines social capital within a system of innovation as trust between institutions and argues that this trust reduces the risk of financing innovation. SMMEs, consultants and mines have weak social capital because they tend to ‘ring fence’ their research and development to maintain their competitive advantage.

Platforms for collaboration within the mine waste sector are available and used for the most part. Agents in the sector seem to gravitate towards more formal means of collaboration. It can be argued that collaboration comes from a need to collaborate on specific projects rather than a culture of seeking collaborative opportunities with other agents or agents. This could be linked back to the unorganised and unsystematic approach to innovation that is prevalent within the sector. The benefits of collaboration in order to bring about innovation in the sector is not recognised by the agents in the sector.

5.6 Innovation funding

A major challenge in any innovation model for many developing countries is funding, especially at full scale level to introduce the innovations to the market and South Africa is no exception. The funding model for an innovation system in research emanating from developed countries is rarely researched to a satisfactory level because of the large spend on R&D as a percentage of GDP by these countries and the availability of venture capital funding by the private sector. Hansen and Rametsteiner (2006) and Malerba (2002) recognise the importance of making financial resources available for innovation but assumes that private sector funding is readily available. Schade (2016) specifically included venture capital as part of the innovation infrastructure instead of the general “funding” found in most literature.

It was found in this study that funding for innovation in the mine waste sector is mostly from government funding institutions like the TIA, IDC and DBSA. A small amount is funded from within the organisation, but none of the organisations interviewed sourced funding from banks
and private investors. Innovation in this sector is capital intensive and very high risk. Commercial banks are risk averse and reluctant to fund innovations within the sector.

The SMMEs interviewed for this study find it difficult to get funding for their innovations because these government funding institutions have a cap on how much they can fund. Where they do get funding from government funding institutions, the turnaround time is long. One SMME had to wait as long as two years for the due-diligence process to be completed, by that time they had already funded the project internally from revenues.

There is a gap in funding for innovations in the sector, which probably extends to other sectors in the country. Funding for research to get innovation from concept to full scale is readily available through organisations like the WRC and the NRF. Bigger organisations like the IDC and the DBSA will only fund market ready innovations, leaving a funding gap between full-scale research and market ready development. The TIA was established to fill this gap but with a funding cap of R50million and the capital intensive nature of innovations in the sector, many innovations in the sector do not get the chance to be introduced to the market.

The private sector, especially mining companies, need to fill this gap in funding in order to advance innovation in the sector. It is difficult to imagine how this could be done without the motivation of legislation and policy governing mine waste management. It has already been established that the enforcement of legislation by government is lax in the sector. Mining companies are already expected (by government) to invest in social initiatives in the communities which they establish mines. It is not unfathomable to put legislative requirements in place for these companies to contribute funding to innovation in managing their waste, which will bridge the innovation funding gap and have a positive impact in reducing mine waste to landfill within the communities they operate in.

It can thus be concluded that funding of innovation within the mine waste sector is available for the most part, from government funding institutions. If the sector is examined through Schade’s innovation infrastructure model, then the element of venture capital is very weak. A lot of the funding is available in the concept stage of innovation but not in the development stages before the innovation is ready for market. It is recommended that the “innovation funding gap” present in the mine waste sector be filled by funding from mine waste producers compelled by enforced legislation.
5.7 Innovation targets

Innovation target setting has had a significant impact in the development of mine waste innovation in the Canadian mine waste sector which is a sector similar to the South African sector in many ways. Industry leaders across Canada and the Mining Association of Canada created Towards Zero Waste Mining, which is the prime innovation strategy for the industry (Kondos and Weatherell, 2014). The main target of the policy is to achieve zero waste in the industry within 20 years.

It was found that there are no government targets regarding minimisation in mine waste and none of the organisation interviewed had any targets of their own. There are, however, targets in place for general waste management in the broader waste management sector. There was a permeating strong view among the respondents that innovation targets need to be set up higher up the value chain (in processing) in order to reduce the resulting waste output rather than at the downstream end of the value chain (beneficiating solid mine waste).

The New Growth Path and the Green Accord by the DED is aimed at developing innovation that address waste minimisation in general with no specific reference to mine waste but none of the participants referred to these documents. This is an indication, and perhaps proof, that implementation of waste management policy in the country is lacking. The research institutions and the DST did mention the waste reduction targets set out in the waste RDI but these are not adopted government policies.

Targets in the mine waste management sector are generally stated (agents knew of the need to minimise) but not quantified and don’t have a clear timeline. This can be attributed to the fact that mine waste has only recently (over the last decade) been classified as waste, before that it was classified as residue and excluded from the waste management planning dialogues. Now that the classification of mine waste is clear in the regulation, mining sector leaders (mining companies, the Chamber of Mines and the government departments that regulate the sector) should set up a clear strategy with timelines regarding the minimisation of mine waste, something similar to the Towards Zero Waste Mining by the Canada Mining Innovation Council. Innovation opportunities to minimise mine waste should be sought not only in beneficiation of waste but also in the mining methods and mineral processing. The RDI roadmap is a good starting point for such a strategy, it should be developed further with specific targets for solid mine waste.
5.8 Incentive to innovate

Incentives to innovate within a system of innovation, sectoral or national, is a key building block to ensure ongoing support of innovative projects. Marleba (2002) states that technological opportunities reflect the likelihood of innovating for any given amount of money invested in research, high opportunities provide powerful incentives to the undertaking of innovative activities. The Mining Indaba and Monitor Deloitte report (2016) also states incentive metrics as one of the building blocks of innovation in the sector.

In this study it was discovered that the DST does offer a 150% tax rebate on research and innovation spend. This incentive, however, is not effectively managed (as conceded by the representative from the DST) resulting in a reluctance from industry to take advantage of it. Most of the participants suggested that rigorous implementation of legislation governing mine waste would serve as an incentive to innovate.

Similar to the study done by Mining Indaba and Monitor Deloitte, it can be concluded that the lack of incentive systems within the mine sector is a significant inhibitor of innovation within the sector. Removing the inefficiency from the current tax rebate incentive, providing more private sector funding for research and development (as mentioned in the Innovation Funding section) and implementation of existing legislation would go a long way in providing high opportunities, as suggested by Marleba, and incentivising innovation within the sector.

5.9 Model of the sectoral innovation system in the South African mine waste sector

The existing mine waste sectoral system of innovation can now be mapped using the model adapted from Hansen and Rametsteiner (2006) as described above. The green arrows represent strong linkages between the agents and the red indicates linkages that should be improved to advance innovation within the sector.
The linkage between the education system and the core agents in the system is strong because all the agents that participated in the study interacted with universities in at least one way. The political system has also contributed significantly to the innovation infrastructure by providing legislation and funding for research and development. The lack of clarity and targets in legislation and inefficient incentive metrics for innovation lead to the conclusion that the framework conditions for innovation need significant improvement. The link between the production system and the infrastructure system, especially private sector infrastructure, is weak because there exists a funding gap within the system that inhibits innovative projects from getting to a market ready level. There should be a stronger link between the production system, mining suppliers and infrastructure with the aim of technology diffusion and knowledge transfer to enable innovation in the sector.

6. Conclusion

The aim of this study was to investigate how the South African mining sector can create an environment conducive to innovating towards reducing mine waste to landfill and grow the sector’s contribution to the green economy through a systems of innovation approach. The
study was guided by two research questions:

It was found that there is science and technology capability within the sector to reduce mine waste to landfill because there are framework conditions created through government legislation, a number of different government departments forming the political system of the sector with a research and education system doing research and development. There is an innovation infrastructure underpinned by government funding institutions and mining standards with a growing number of SMMEs within the production system.

Using a sectoral system of innovation model adopted from Hansen and Rametsteiner (2006), strong and weak linkages between the agents of the sector were identified. The following recommendations were provided to improve the existing structure:

- Drafting of clear, coherent and unambiguous legislation and policy for solid mine waste management through a collaboration between research institution, mining companies and government. Enforcement of the legislation is of paramount importance.
- A systematic approach to innovation at national and organisational level through an innovation strategy for the sector.
- Research into mine waste reduction needs to form part of the national waste agenda.
- The agents of the system need to pursue collaborative opportunities with the end goal of knowledge transfer and technology diffusion.
- The innovation “funding gap” currently present in the sector should be filled by mine waste producers.
- Develop the RDI roadmap further in include a clear strategy for mine waste minimisation with timelines.
- Removing the inefficiency from the current tax rebate incentive, providing more private sector funding for research and development and implementation of the existing legislation would incentivise innovation within the sector.
REFERENCES


APPENDIX A:

Schedule of interview questions
1. General Questions

1.1. Please give a brief background pertaining to the role you play within your organisation and your experience with regards to mine waste management in that role

1.2. What is your organisation’s role in mine waste management in South Africa and what are some of the achievements that have been achieved by your organisation in that regard?

2. Legislation and Policy

2.1. Is there clarity in the legislation and policy around mine waste management in South Africa? Please feel free to expand where you deem it necessary?

2.2. How does your organisation implement policy and legislation related to the minimisation of mine waste to landfill in South Africa?

3. Approach to Innovation

3.1. Does your organisation encourage innovation? If so how does it encourage innovation?

3.2. How has your organisation contributed to innovation in the mine waste management sector?

3.3. What are the key elements that enables your organisation to be innovative?

4. Human Resource Capability

4.1. What skills are needed for your organisation to contribute meaningfully to the management of mine waste?

4.2. Is your organisation adequately resourced with people who can contribute meaningfully to mine waste management in South Africa?
5. Research and Development

5.1. Is there enough research and development done in the area of mine waste management, particularly in mine waste reduction?

5.2. How would you characterize the level of learning and technology diffusion that takes place in the South African mine waste management sector?

5.3. How has your organisation contributed to the production of new knowledge in the mine waste management sector?

6. Collaboration and Interaction

6.1. Are there platforms available to your organisation for collaboration with other stakeholders in the mine waste management sector?

6.2. Briefly describe how any collaboration with other stakeholders outside your organisation has influenced developments in mine waste management.

6.3. Does your organisation interact or engage with institutions of higher education or research?

6.4. Which other organisation, in the mine waste management sector, does your organisation interact with?

7. Innovation Funding

7.1. If your organisation had an innovative idea it wants to develop within mine waste management, how would it go about funding such an innovation?

7.2. Are government finance institutions willing to fund innovation in mine waste management? If so, which institutions?

8. Innovation Targets
8.1. Are the government’s targets regarding reduction in mine waste to landfill are clear to you and your organisation?

8.2. Does your organisation have any targets of its own regarding management of mine waste? If yes, what are these targets?

9. Incentive to Innovate

9.1. Are there any incentives within or outside your organisation to innovate within mine waste management?

9.2. What do you think would incentivise innovation in mine waste management?