

**Sustainability performance analysis and decision-making for minerals
beneficiation: a South African iron and steel scrap case study**

By

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requirements for the degree of Master of Philosophy
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Executive Summary

It is widely accepted that downstream mineral resource beneficiation has the potential to promote socio-economic growth in resource-rich nations. Many African countries, including South Africa, are thus prioritizing mineral beneficiation in their national policies and development strategies. However, policies with a strict focus on promoting downstream mineral beneficiation may come at the expense of other emerging sectors, as well as overshadow potential economic benefits of cross linkages into lateral sectors. Therefore, when presented with different beneficiation alternatives for a particular commodity, decision makers ideally need to base decisions on a systematic analysis of positive and negative impacts, if the sustainability benefits are to be maximised.

Decision support frameworks (DSF) have been recommended for the promotion of sustainable development in the minerals sector, in particular for corporate and public policy development. They provide a structured and systematic approach to decision-making in complex situations, often characterised by multiple decision-makers with potentially conflicting views and objectives. Furthermore, the structured approach allows for transparent decisions to be made which take into consideration both the decision situation and stakeholder perspectives. Research thus far, on DSFs in the minerals sector, has been in the context of mineral processing decision situations which were primarily concerned with technology selection or process design.

This dissertation investigates the applicability of decision support frameworks for sustainability performance analysis and comparison of decision alternatives, aimed at strategic planning in the minerals sector. More specifically, this entails the sustainability performance evaluation of decision alternatives as well as exploration of stakeholder perspectives regarding the relative importance of different factors in the decision-making process. The dissertation places particular emphasis on the different steps outlined in DSFs, rather than the final decision outcome, enabling analysis of the value that may be gleaned from the DSF as a whole, and from the individual stages.

The application of decision support frameworks is demonstrated for the case of the iron and steel scrap industry in South Africa, with a particular focus on the potential for increased local beneficiation of scrap in steel mills and/or foundries. The export of scrap metal has been identified as a significant concern to some, as it is viewed to come at the expense of local beneficiation, hampering access to affordable and quality scrap for local processors. As such, decision-makers are faced with the question of which option for scrap metal processing has the most potential sustainability benefits. The sustainability performance evaluation was based on available industry data, and assumptions were made when data were unavailable. Interviews were conducted with key stakeholders in the industry, which included representatives of metal recycling, steel mills, foundries and institutions.

The iron and steel scrap industry was found to be facing a myriad of sustainability issues, including economic, environmental and socio-economic issues. Although scrap availability was a concern to scrap processors, none of them were opposed to the export of scrap in principle. Instead their concerns surrounded the availability of good quality scrap suitable for local processing. When it comes to the relative influence of the different sustainability issues on the decision-making process, stakeholders were found to prioritise micro-economic issues directly related to financial performance. In contrast, relatively less emphasis was placed on environmental issues which were commonly viewed in terms of

the financial implications of legislative requirements. However, the consideration of purely economic indicators in the comparison of alternatives would have led to a misrepresentation of the sustainability benefits associated with the respective alternatives. In general, steel mills performed best when compared according to financial indicators. However, they were associated with higher atmospheric emissions and lower socio-economic benefits. Foundries displayed higher potential socio-economic benefits which were related employment creation and skills development. The export of scrap effectively had negligible local environmental impacts as the recycled scrap does not undergo any further process prior to exporting. In essence the environmental burden associated with scrap processing is shifted to the destination country. These results illustrated the complexities associated with multiple criteria decision-making.

The findings of this dissertation suggest that decision support frameworks have the potential to play a valuable role in strategic planning in the minerals sector. However, the extent to which they are applicable are highly dependent on the decision situation. In existing industries, DSFs facilitate informed decision-making based on the current health of an industry as well as long-term potential sustainability benefits that could be realised from changes being made in the industry. Furthermore, the stakeholder consultation process enables the exploration of the underlying complexities and factors that contribute to any challenges an industry may be facing, as well as their effect on different stakeholders. Ultimately, this enables the development of well-informed targeted strategies and policies that take into consideration the realities of the industry as well as stakeholder perspectives, increasing the likelihood of their success.

Statement of Originality

I know the meaning of plagiarism and declare that all of the work in the dissertation, save for that which is properly acknowledged, is my own.

Takunda Yeukai Chitaka

28 September 2015

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Chapter 1 Introduction

Mineral resources provide essential materials to human society and its development. They make up a part of numerous products and are thus an integral part of every sector of the economy. Despite Africa being a top producer of a number of mineral commodities, many African countries primarily export their minerals and metals in their unprocessed forms (Hausmann et al. 2008; AU 2009). The need for industrialisation on the continent is widely acknowledged and resource-based development strategies are seen as the key to catapulting “Africa to modernization” (AU 2009). However, exploitation and beneficiation of mineral resources are associated with a myriad of sustainable development challenges, including various economic, environmental and social issues (Azapagic 2004). Consequentially, there is increasing pressure on the African industry to meet the demand for minerals in a manner that is consistent with the principles of sustainable development (Shields & Solar 2000; Azapagic 2004).

1.1 Background

1.1.1 Mineral Beneficiation as an African Mandate

An increasing propensity of occurrences of minerals exploitation in developing countries has led to many becoming heavily reliant on their primary extractive sectors as a source of wealth and economic growth (Kumah 2006). This has the potential to radically alter the social and economic landscape of a nation including the promotion of corruption and inequitable distribution of wealth. The minerals sector has the potential to provide many benefits, including employment opportunities and generation of wealth, as well as providing much needed foreign direct investment (FDI) in the case of poorer countries (Azapagic 2004; UNECA 2011; ICM 2012). However, the realization of these benefits is dependent on the management and distribution of mineral wealth and revenues (Azapagic 2004; Kumah 2006). The sector also presents abundant opportunities for the diversification of a nation’s economy, yet many developing countries have been unable to maximize on this (Azapagic 2004; Kumah 2006; AU 2009; Morris et al. 2012; SDSN Thematic Group 10 2013). A focus on short-term returns, often based on production volumes rather than value-adding activities, has led to reckless exploitation of mineral resources in some cases. This has led to faster depletion of resources, greater negative environmental impacts with little economic benefits returned to society (Azapagic 2004). Downstream minerals beneficiation has been proposed to help offset this unsustainable depletion of resources, maximizing returns to the sector and enabling countries to derive more benefits from their resources (Azapagic 2004; AU 2009; SDSN Thematic Group 10 2013).

Beneficiation can be described as the further processing of a mineral from the stage where it represents a saleable raw material from mining through to a finished manufactured product for consumers (Robinson & von Below 1990; Baxter 2005). Mineral beneficiation is commonly referred to as value-addition whereby increased processing signifies the creation of a higher value product. In order to compare levels of beneficiation, the processes can be classified into four generic stages, as shown in Table 1-1. The separation of the four stages into either the mining or manufacturing industry is a key factor to the debate as to why mining companies have not invested more into downstream beneficiation (Baxter 2005). The separation is deemed necessary as the skills and competencies required for mining differ from those required for manufacturing (Baxter 2005; Turok 2013; Bamieh 2014).

Table 1-1: The four stages of mineral beneficiation (Robinson & von Below 1990; Baxter 2005)

Stage	Process Category	Product	Labour Intensity	Capital Intensity	Industry Cluster
1	Mining and production of an ore or concentrate	Processed raw materials	High	High	Mining
2	Conversion of concentrate into a bulk tonnage intermediate product	Fabricated alloys	Low	High	Mining / Metallurgy
3	Conversion of intermediate goods into a refined product suitable for purchase by industries	Semi-manufactured articles	Low	High	Refining/ Manufacturing
4	Manufacture of a final product for sale	Fabricated articles	Medium - High	Medium - High	Manufacturing

Across Africa governments are looking towards mineral beneficiation as a path towards greater socio-economic empowerment (Stewart et al. 2001; Azapagic 2004; SDSN Thematic Group 10 2013; Bamieh 2014). They are trying to move away from a strict focus on activities in the mining industry cluster and instead encourage value-adding activities typical of manufacturing. Many African countries, including South Africa, are thus prioritizing mineral beneficiation in their national policies and development strategies, turning beneficiation into somewhat of an African mandate. They are of the view that harnessing natural resources, through the development of value-adding industrial linkages, is the “key to Africa’s development” (AU 2009; Bamieh 2014). Policies such as the Africa Mining Vision aim to encourage critical linkages to integrate the minerals sector into the local economy in the hopes of creating a diversified and globally competitive industrialised African economy (AU 2009). Bolton and Doepel (2013) also highlight the potential for cross-linkages to create lasting benefits and a more robust and resilient economy. There are generally three broad categories of linkages (AU 2009; Ramdoo 2013):

- **Backward or upstream linkages** related to industries that supply inputs to the mining sector, including mining capital goods, consumables and service industries.
- **Forward or downstream linkages** consisting of industries that utilise inputs from the mining sector into other activities, i.e. into mineral beneficiation and manufacturing.
- **Horizontal or side-stream linkages** which consist of developing activities that may not be directly linked to the extractive sector but have the potential to unlock business and employment opportunities in other sectors of the economy. This includes linkages into infrastructure, and skills and technology development.

1.1.2 Mineral Beneficiation as a Good or Bad Policy Paradigm

Despite all the perceived benefits of downstream beneficiation, Hausmann et al. (2008) describe beneficiation as “a bad policy paradigm”. The results of their study, which evaluated the relationship between forward linkages and structural transformation, suggested that policies to encourage downstream beneficiation are often misguided and justified using logic and anecdotes rather than systematic analysis. The SDSN Thematic Group 10 (2013) also emphasised the importance of decision-making based on systematic analysis in the sustainable management of natural resources. The report highlighted the complexities involved in deciding to invest in value-addition, stating that a common mistake made by governments is focusing too much on “imagined value addition opportunities” in the minerals sector. Stewart et al. (2001) suggest that the only way for the minerals sector to successfully

shift from resource extraction to “added-value” commodities provision is through the development of mechanisms which can systematically explore the trade-offs between environmental, social and techno-economic objectives. These mechanisms will assist in the promotion of sustainable development within the industry and ensure transparency, defensibility and accountability for decisions taken.

Many policies and strategies to encourage and promote downstream beneficiation draw heavily on the experiences of Nordic countries in resource-based development and industrialisation. Research conducted into how these countries successfully managed their natural resources found that although there were abundant socio-economic benefits, the paths followed by these nations are difficult to replicate (Morris et al. 2012; SDSN Thematic Group 10 2013). This emphasised the fact that attempting to encourage downstream mineral beneficiation will not automatically translate into sustained socio-economic growth (Morris et al. 2012). Instead, policies with a strict focus on promoting downstream mineral beneficiation may come at the expense of other emerging sectors, as well as overshadow potential economic benefits of cross linkages into lateral sectors (Hausmann et al. 2008). Heavy investment in adding value in this sector also has the potential to increase dependence on it, which may pose greater problems once the resources are depleted and more adjustments are needed to the economy (SDSN Thematic Group 10 2013).

Nonetheless, governments are seeking to promote local downstream beneficiation activities through policy and direct intervention, with mixed results (Bamieh 2014). In 2011, Zimbabwe banned the export of unrefined chrome ore in an effort to develop local refining capacity (Bamieh 2014). This ban was later relaxed after it was estimated to have cost the country millions in revenue. A lack of processing capacity resulted in massive job losses for miners who had no access to smelters with mining companies being forced to shut down, with other miners divesting into gold mining (Nyamanzwa et al. 2013). Instead of attempting to make it economically viable to beneficiate locally, the Zimbabwean government sought to force mining companies to work with a manufacturing sector that was virtually non-existent. However, some countries have found success with mineral beneficiation, of which Botswana is a prime example. Botswana was successful in developing downstream diamond processing with De Beers relocating its formerly London-based activities to Gaborone (Bamieh 2014). This was enabled by the establishment of an attractive environment by the government, including infrastructure provided in the specially designed Diamond Technology Park. Additionally the government has been praised for adopting reasonable regulations on employment, taxes and currency exchange, as well as its willingness to provide financial assistance to diamond processors (Grynberg 2013; Bamieh 2014). The success of beneficiation in Botswana is also attributed to a fundamental shift in De Beers’ corporate strategy (Grynberg 2013). Although De Beers was historically an opponent of downstream processing in Africa, its weakening in international markets and its continued reliance on African supply resulted in its shift to favour beneficiation for the prospect of long term access to Botswana’s rough diamond supply.

1.1.3 Decision-Making for Responsible Minerals Beneficiation

As shown in the cases of Zimbabwe and Botswana, governments face a complex set of decisions when it comes to sustainable management of natural resources, particularly in the minerals sector. There are a number of factors that need to be taken into consideration when deciding to invest in value-adding activities. Before the decision is made to invest heavily in value-add activities it is necessary to perform an examination of potential resource types (SDSN Thematic Group 10 2013). The examination should

take into consideration the quantity and lifetime of resources, the scale of domestic demand as well as how easily the resource is traded internationally (Robinson & von Below 1990; Ramdoo 2013; SDSN Thematic Group 10 2013). Identification of strategic linkages is also a key element in the identification of opportunities that will provide maximum potential benefits (Hausmann et al. 2008; Ramdoo 2013). When it comes to the development of downstream linkages a crucial strategic question is “*how far is it economically feasible and justifiable to adopt a value-add strategy for mineral beneficiation*” (Ramdoo 2013)? In other words, at which stage in the mineral beneficiation process does it stop being justifiable to pursue value-adding activities, based on the sustainability performance? Therefore, a key challenge to sustainable development in the minerals sector is the selection of a sustainable option from a set of alternatives due to the complexities associated with the decision making process (Azapagic & Perdan 2005a).

Decision support frameworks (DSF) have been recommended for the promotion of sustainable development in the minerals sector, in particular for corporate and public policy development (Azapagic & Perdan 2005a; Petrie et al. 2007). A DSF can be considered to be a management protocol which facilitates decision-making in complex situations, often characterised by multiple decision-makers with potentially conflicting views. The framework is generally structured into three steps: problem structuring which serves to develop an understanding of the decision situation, problem analysis in which the alternatives are compared and problem resolution when the chosen alternative is implemented and monitored (Azapagic & Perdan 2005a). The structured approach allows for informed and transparent decisions to be made which take into consideration the decision situation as well as the perspectives of different stakeholders. Research thus far (discussed in chapter 2) has investigated their applicability in mineral processing decision situations which were primarily concerned with technology selection or process design (Stewart 1999; Notten 2001; Stewart et al. 2001; Basson 2004). Furthermore, there has been more emphasis placed on the environmental aspects of sustainability.

1.2 Problem Statement

There is a growing prioritisation and promotion of downstream mineral beneficiation in resource rich African nations due to its potential to promote socio-economic growth. Decisions surrounding downstream mineral beneficiation are complex due to the multitude of factors to be considered to ensure maximum sustainable benefits are realised. This necessitates an approach which facilitates transparent and defensible decision-making. Although decision support frameworks have been recommended for strategic planning in the minerals sector, their applicability for this use is yet to be investigated.

1.3 Dissertation Objectives and Approach

Thus the objective of this dissertation is as follows:

<p>To investigate the applicability of decision support frameworks for sustainability performance analysis and comparison of decision alternatives for mineral beneficiation.</p>
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To do this, a generic DSF is applied to one sector, as a case study, being the South African iron and steel scrap industry, with a particular focus on the potential for increased local beneficiation of scrap steel. More specifically, this entails the evaluation of beneficiation options according to their sustainability performance as well as exploring stakeholder value systems and their potential influence on the decision-making process.

The case study approach is commonly used in decision-making research, due to its ability to provide a deeper understanding on what was done and why (Nutt & Wilson 2010). The approach is particularly useful as it enables explicit discussion of the application. The application of case study approaches in the development of decision-making theory in minerals processing set precedent for its adoption in this dissertation (Stewart 1999; Stewart et al. 2001; Basson 2004).

1.4 Scope

This dissertation investigates the applicability of decision support frameworks to facilitate sustainability performance analysis and decision-making for mineral beneficiation. Iron and steel has been identified as one of five mineral resource based value chains which the South African government believes to have the greatest potential for value addition through beneficiation (DMR 2011). Therefore, supporting and growing the industry – with a particular focus on the sustainable promotion of downstream beneficiation – is a key government priority (DMR 2011). Iron and steel is of interest not only due to the variety of beneficiation opportunities it provides, but the sector also requires feedstocks that include a number of strategic commodities. There are a range of potential processing routes for steel manufacturing. Furthermore, the value chain presents strong opportunities for recycling at the end of products' service lives. As such the value chain presents a number of opportunities for potential growth.

This dissertation is focused on the application of decision support frameworks on a chosen opportunity identified within the iron and steel value chain. Increased local beneficiation of iron and steel scrap has been identified as a key opportunity in this industry, therefore the case study developed in this dissertation is focused on the iron and steel scrap industry.

1.5 Context for the Dissertation

The KwaZulu-Natal Department of Economic Development, Environmental Affairs and Tourism have appointed the Minerals to Metals Initiative within the Department of Chemical Engineering at the University of Cape Town in collaboration with The Green House to develop a mineral beneficiation strategy for the region. This collaborative effort, referred to as the “KZN Project” in this dissertation, seeks to develop a provincial minerals beneficiation strategy focused on the promotion of sustainable development. This dissertation forms part of the KZN Project and aims to contribute to it by investigating the applicability of decision support frameworks for decision-making for minerals beneficiation and what value might be gleaned from its application in the development of a minerals beneficiation strategy. This includes the development and application of a practical means of measuring and assessing the sustainability performance of different mineral beneficiation options. The research will incorporate data and information resulting from KZN Project tasks, including analyses conducted on the iron and steel value chain.

1.6 Dissertation Structure

The structure of this dissertation is presented schematically in Figure 1-1. Following the introduction of the dissertation in this chapter, a review of relevant literature is presented in Chapter 2. This includes a review of the current status of sustainable development in the minerals sector, as well as an analysis of decision support frameworks which are the focus of this dissertation.

The research methodology used in this dissertation is outlined in Chapter 3, including the research questions that guided the research.

Chapters 4 to 6 present the findings of the case study resulting from the application of a generic DSF on the South African iron and steel scrap industry, with a particular focus on the potential for increased local beneficiation of scrap. These chapters have been structured according to the different stages outlined in the generic DSF presented in Chapter 3. The results of the problem structuring phase are presented in Chapter 4, which serves to provide an understanding of the decision situation. Chapter 5 explores stakeholder value systems with regards to decision-making in this context, including the relative influence of different sustainability issues. The results of the sustainability performance analysis are presented in Chapter 6.

Chapter 7 consolidates the results presented in Chapters 4 to 6 and provides a discussion surrounding the implications of the finding with regards to the objective of the dissertation as well as recommendations for future work.

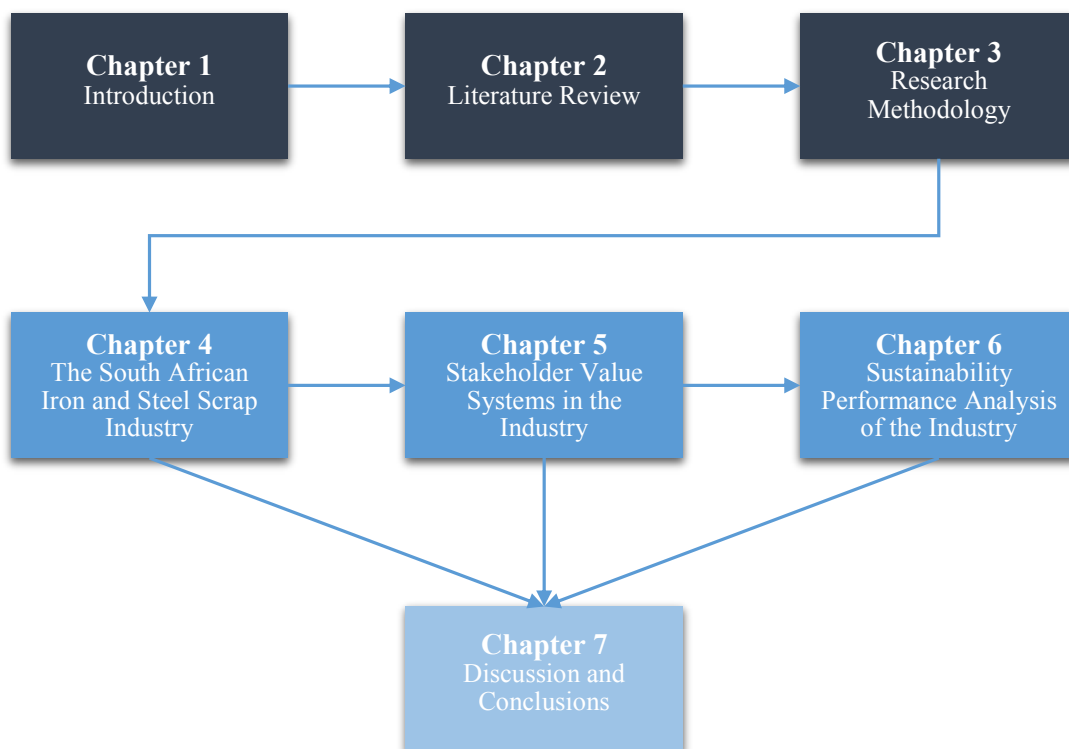


Figure 1-1: Dissertation structure schematic

Chapter 2 Literature Review

The aim of the literature review is to provide an analysis of the status quo regarding sustainability performance assessment and decision-making in the minerals sector. The chapter begins with a review of different sustainable development initiatives within the minerals sector. The proceeding section (2.2) discusses sustainability performance assessment which is based on the development of indicators. Sustainability indicators are integral to sustainability performance assessments as they translate sustainability issues into qualitative and quantitative measures (Belton & Stewart 2002; Basu & Kumar 2004; Bell & Morse 2008). The review then goes on to discuss the generic decision-making procedure that forms the basis of decision support frameworks, which are the focus of this dissertation. The section provides an expansion on the different stages of decision-making mentioned in section 1.1.3, namely problem structuring, problem analysis and problem resolution. This includes the characterisation of factors that influence decision-making, including the role of decision situations and the integration of stakeholder perspectives into the process. A section on scrap metal recycling is provided in the review so as to contextualise the role of the scrap metal industry.

2.1 Sustainable Development in the Minerals Sector

Since the introduction of the term sustainable development in the Brundtland Commission's Report *Our Common Future*, 1987, numerous definitions of the term, sustainable societies and sustainable economies have been proposed which often provoke different responses (Mebratu 1998; Hilson & Basu 2003; Hopwood et al. 2005). Within the minerals sector, there have been a number of initiatives to promote sustainability. These include sustainability principles developed by the Mining, Minerals and Sustainable Development project (MMSD), the International Council on Mining and Metals (ICMM) as well as national initiatives.

2.1.1 The Mining, Minerals and Sustainable Development Project

The MMSD project represents one of the largest projects by the global mining sector to address the importance of sustainable development (Tuazon et al. 2012). It has a strong focus on governance and interaction between the company and community in decision-making. The framework developed, i.e. the "Seven Questions Framework" (summarised in Table 2-1), is intended to be applied to the primary mining sector, including exploration, mining, refining or primary metals manufacturing, fabrication and recycling, and spans the mines entire project life cycle to final post-closure. The framework was designed to guide the assessment of a project or operation's net contribution to sustainable development and whether or not it is positive over the long term. This is done via the "Seven Questions" approach whereby an ideal answer is offered for each of the questions and a hierarchy of objectives, indicators and specific measurements are suggested (IISD 2002).

Table 2-1: MMSD Seven Questions Framework (IISD 2002)

MMSD Seven Questions Framework	
Engagement	Are engagement processes in place and working effectively?
People	Will people’s well-being be maintained or improved?
Environment	Is the integrity of the environment assured over the long term?
Economy	Is the economic viability of the project or operation assured and will the economy of the community and beyond be better off as a result?
Traditional and non-market activities	Are traditional and non-market activities in the community and surrounding area accounted for in a way that is acceptable to the local people?
Institutional arrangements and governance	Are rules, incentives, programs and capacities in place to address project or operational consequences?
Synthesis and continuous learning	Does a full synthesis show that the net result will be positive or negative in the long term, and will there be periodic reassessments?

2.1.2 The International Council on Mining and Metals Principles

The ICMM developed a set of 10 sustainability principles specifically for the mining and metals sector that subscribe to enhanced holistic outcomes environmentally, socially, economically and ethically (Tuazon et al. 2012). These were based on issues identified in the MMSD project and were benchmarked against leading international standards including the Rio Declaration, the Global Reporting Initiative (GRI), the Organisation for Economic Co-operation and Development Guidelines for Multinational Enterprises, the social and environmental Safeguard Policies of the International Finance Corporation (part of the world bank group) and the Voluntary Principles on Human Rights and Security (ICMM 2003). When it comes to reporting on sustainability, the ICMM promote the use of GRI Sustainability Reporting Guidelines as well as the GRI Minerals and Metals Disclosures.

Table 2-2: ICMM Sustainable Development Principles (ICMM 2003)

The 10 ICMM Principles	
1.	Implement and maintain ethical business practices and sound systems of corporate governance
2.	Integrate sustainable development considerations within the corporate decision-making process
3.	Uphold fundamental human rights and respect cultures, customs and values in dealings with employees and others who are affected by our activities
4.	Implement risk management strategies based on valid data and sound science
5.	Seek continual improvement of our health and safety performance
6.	Seek continual improvement on our environmental performance
7.	Contribute to conservation of biodiversity and integrated approaches to land use planning
8.	Facilitate and encourage responsible product design, use, re-use, recycling and disposal of our products
9.	Contribute to the social, economic and institutional development of the communities in which we operate
10.	Implement effective and transparent engagement, communication and independently verified reporting arrangements with our stakeholders

The principles have elements in common with other frameworks such as the Bellagio Principles (Bell & Morse 2008) and The Natural Step (Robèrt 2000). McLellan et al. (2009) suggest that the framework may be overinclusive in its classification of sustainable development in some cases whilst neglecting important issues such as land usage and impacts associated with by-products. However, although these issues are not explicitly addressed in the principles the recommendation of the GRI guidelines effectively ensures that they are included in sustainability assessments.

2.1.3 South African Sustainable Development in Mining Initiative

The South African Sustainable Development in Mining Initiative aims to develop a strategic framework for monitoring the mining industry’s contribution to sustainable development, to aid relevant decision-makers and track progress over time (DME 2007). The monitoring system is structured using a Principles-Criteria-Indicators (PCI) approach. A set of principles that encapsulated the broad goals of the sector was first developed, after which criteria that will enable to achievement of the broad goals were determined. The indicators were to serve as practical tools that measure progress towards achievement of the goals, however, to date no actual indicators have been developed. The PCI set has been informed by key literature including MMSD reports, ICMM principles, the GRI and research performed by Azapagic (2004).

Table 2-3: Preliminary Principles of the Sustainable Development in Mining Initiative (DME 2007)

Preliminary Principles of the Sustainable Development in Mining Initiative	
1.	Maximise the contribution of the mining sector to national economic development
2.	Contribute to the socio-economic development of South Africa
3.	Expand opportunities for historically disadvantaged persons
4.	Develop and strengthen health and safety programmes and initiatives
5.	Promote responsible practice
6.	Contribute to achieving sustainable (efficient) patterns of production and consumption
7.	Reduce impact on life support systems and the ecological services they provide
8.	Develop effective partnerships and communication networks to promote good governance
9.	Ensure the ability of government (i.e. the DME) to fulfil its mandate

2.2 Sustainability Assessment and Evaluation

Measurement of sustainable development is an essential prerequisite to promoting a sustainable society (Mitchell 1996). Therefore, sustainability assessment is increasingly being viewed as an important element in the shift towards sustainable development (Ness et al. 2007). Devuyst et al. (2001 quoted by Ness et al. 2007) define it as “a tool that can help decision-makers and policy-makers decide which actions they should or should not take in an attempt to make society more sustainable”. There are a variety of approaches and tools that may be used in the assessment and comparison of different alternatives during problem analysis. The type of method employed is highly dependent on the type of decision that needs to be made, the decision context as well as the overall objectives of the entire process. Integrated assessment consists of a wide array of tools for managing complex issues in decision-making (Gough et al. 1998). In the context of sustainable development, integrated assessment tools are based on systematic analysis and are often designed as “technical tools” to simulate scenarios for decision-makers (Gough et al. 1998; Ness et al. 2007). Sustainability assessment tools are often comprised of indicators and metrics. For example, Life Cycle Assessment is an assessment tool whose results are presented in the form of performance indicators such as global warming potential. The application of tools and methodologies, through the use of indicators, enables a better comprehension of what sustainability means in practice as well as providing a practical means of evaluating sustainability (Tuazon et al. 2013).

2.2.1 Sustainability Indicators

The assessment of sustainability performance can be achieved through the use of sustainability indicators which directly translate sustainability issues into quantitative and qualitative measures of performance making it possible to measure the behaviour of a system (Belton & Stewart 2002; Basu & Kumar 2004; Bell & Morse 2008). Indicators are directly linked to different aspects of sustainable development, translating high level concepts and definitions into practical means of evaluating sustainability (Tuazon et al. 2013). In the context of sustainability decision-making, indicators are a key aspect of multicriteria decision-making frameworks, forming the basis of the evaluation between alternatives (Belton & Stewart 2002; Ibáñez-Forés et al. 2014). There has been increasing popularity in the use of sustainability indicators as practical means to gauge sustainability performance, enabling stakeholders to not only report on their performance but as a means of alternative comparison (Bell & Morse 2008; Ibáñez-Forés et al. 2014). Therefore, sustainable development indicators (SDI) can be seen as playing a crucial role in clarifying what is meant as sustainable development as well as providing a

practical means of measuring performance, enabling stakeholders to make the relevant steps towards its promotion (Levett 1998).

2.2.1.1 Indicator development

There are two distinctive approaches for indicator selection and/or development: top-down and bottom-up approaches. Most often a top-down approach is used whereby indicators are selected to fit a sustainability framework, such as the ones reviewed in section 2.1 (Tuazon et al. 2013). The definition of the framework and set of SDIs is usually done by experts and researchers (Singh et al. 2012). This approach is objective led, starting with a general statement of overall objectives and continuous expansion of these values into more detailed concepts until measurable indicators, are obtained (Belton & Stewart 2002). In contrast, multi-stakeholder engagement in the design of the framework and SDI selection process is a crucial element of the bottom-up approach (Singh et al. 2009; Tuazon et al. 2013). The bottom-up approach is alternative led, beginning with elicitation of detail simulated by thinking about the strengths and weaknesses of available alternatives (Belton & Stewart 2002). These strengths and weaknesses are then translated into indicators. Tuazon et al. (2013) recommend a combined approach so as to ensure adherence to fundamental sustainability principles as well as practicality and applicability to the task at hand.

A key criticism of indicators is that they are a “classic set of reductionist tools” that attempt to encapsulate complex and diverse issues potentially over simplifying them in the process (Bell & Morse 2008). Levett (1998) emphasizes the importance of context and advocates for the use of a “fitness-for-purpose” approach using different indicator sets for different purposes. As many indicators are constantly being generated for general applicability, they tend to lack a connection to the local context which is essential to gauge the real impact of a system (Tuazon et al. 2013). A number of guidelines have been developed to aid the rigorous process of SDI selection (Bossel 1999; Veleva & Ellenbecker 2001; Bell & Morse 2008). Belton & Stewart (2002) give eight guidelines for indicator selection in order to ensure effective use of indicators in multi-criteria decision analysis:

- **Value relevance:** decision-makers must be able to link each indicator to their goals.
- **Understandability:** it is important to have a shared understanding of the concepts and indicators.
- **Measurability:** if possible, indicators should be measurable and quantifiable; however different approaches require different levels of precision and degree of explicitness.
- **Non-redundancy:** ideally, each indicator should measure a different factor to avoid a concept being attributed greater importance due to it arising under different headings (i.e. double counting).
- **Judgemental independence:** indicators should be independent of each other so that the preference of one indicator is not dependent on the level of another.
- **Balance of completeness and conciseness:** all important aspects of the problem should be captured whilst keeping the level of detail to the minimum required.
- **Operationability:** the amount of information and detail required by indicators should not place excessive demands on decision-makers.
- **Simplicity vs complexity:** indicators should be as simple as possible whilst still capturing the essence of the sustainability issue.

2.2.1.2 Sustainability indicator categories

Sustainability indicators are often organised into categories resulting in the formation of an indicator framework. Most sustainability indicator frameworks are based on the triple bottom line sustainability model and hence typically address the three pillars of sustainable development: environmental, economic and social. Due to the complex nature of sustainable development and the many inter-relationships that exist between the three pillars some frameworks now incorporate a fourth dimension commonly described as institutional (also referred to as cultural or political) which was introduced by the United Nations Commission on Sustainable Development (UNCSD) approach to sustainable development indicators (Basu & Kumar 2004; Labuschagne et al. 2005; Dahl 2012). It is possible to see the same themes recurrent in different indicator categories depending on the perspective at hand. For example, the issue of climate change can be viewed from an environmental perspective, but it may also have financial implications for an organisation further framing it as an economic issue. Solid waste is another example that can be viewed from a variety of perspectives: in the social context, waste can pose a health and safety hazard to surrounding communities, the disposal of solid waste has financial implications (economic) and from an environmental perspective it can be viewed as a threat to biodiversity. Composite indicators, which are formed from the aggregation of a number of indicators, can be used to summarise complex issues (Saisana & Tarantola 2002; Singh et al. 2012).

Economic indicators

Economic indicators measure the economic impact of a company on stakeholders and economic systems at local, national and global levels (Azapagic 2004). Economic issues may be viewed from either a micro or macro perspective. Micro-economics is primarily concerned with company performance related to minimising costs and maximising profits and shareholder returns. Economic benefits on company level may lead to macro-economic benefits on a national level. The choice of focus is highly dependent on the aims of the assessment as well as the target audience. However, an incorporation of both perspectives is possible, as demonstrated by Labuschagne et al. (2005) whereby the economic indicators had an internal focus and the external impacts were considered under the umbrella of social sustainability as socio-economic aspects. Examples of internal impacts include the economic performance of a company such as its contribution to gross domestic product as well as market share performance.

Environmental indicators

Environmental indicators can be described as quantitative descriptors of changes in either the state of the environment or of environmental pressures (Opschoor & Reijnders 1991; Hilson & Basu 2003; Bell & Morse 2008). “State” indicators describe the state of a variable whereas “pressure” indicators gauge a process that will influence a state indicator. It is also possible to integrate the two types of indicators. In comparison to economic and social indicators, environmental indicators are considered to be the most developed and have achieved the highest degree of consensus among experts (Azapagic 2004). The most common indicators relate to air, water, land, and mineral and energy resources (Labuschagne et al. 2005).

Social indicators

Relative to economic and environmental performance, social sustainability is not easy to measure and is commonly recognised as the weakest pillar (Briassoulis 2001; Azapagic 2004; Labuschagne & Brent 2006). One of the reasons is that many of the variables in social and ethical dimensions, such as human

rights or cultural values, are difficult to define and hardly quantifiable. Another key reason for the imbalance is that the focus placed on social sustainability has been marginal compared to economic and environmental. The acknowledgment of the existence of various stakeholders within and outside the system is essential when developing social indicators. Social indicators can include aspects of employment (job creation, wages, training and education), welfare (employee health and safety), human rights issues (empowerment, equity, child labour, and redress) and the impact of the system's activities on different levels of society, which includes surrounding communities (Labuschagne et al. 2005; Petrie et al. 2006). Due to the expansive nature of social indicators it is common for frameworks to include both qualitative and quantitative indicators, as appropriate (Azapagic 2004; Ibáñez-Forés et al. 2014).

Institutional sustainability

Institutional sustainability addresses issues of governance, values and other factors that may be deemed necessary for humanity to prosper (Dahl 2012). These include general strategic issues concerning ethical considerations, public acceptability and corporate image (Petrie et al. 2007). According to the UNCSO appropriate legal and policy instruments are required as an institutional framework to “encourage and implement sustainable development” (UNCSO 2001). Core indicators under the theme should illustrate a country's willingness and commitment to shift from a segmented sector approach to a more holistic sustainable development process. Two key indicators, within the framework, that address this theme are “national sustainable development strategy” and “implementation of ratified global agreements”. Institutional sustainability may be considered as part of the foundation upon which sustainability pillars are built (Basu & Kumar 2004; Labuschagne et al. 2005). Good governance is seen as imperative to the successful implementation of social, economic and environmental objectives and is seen as helpful in establishing corporate sustainability and the targets for project sustainability (Basu & Kumar 2004).

Composite indicators

Development of composite indicators (also referred to as indices) through aggregation is often useful in focusing attention and can be used to summarise complex or multi-dimensional issues (Saisana & Tarantola 2002; Singh et al. 2007). Composite indicators are capable of providing the ‘big picture’ which may be easier to interpret than analysing individual indicators (Saisana & Tarantola 2002). This can help in attracting public interest by providing a summary figure which can be used to compare the performance of systems, particularly countries, and their progress over time.

However, aggregation is not always feasible due to the large amounts of information required to reflect all relevant processes in a system (Opschoor & Reijnders 1991; Saisana & Tarantola 2002). Mitchell (1996) argues against the use of composite indicators alone at local or regional levels due to patchy detail availability. Although single aggregated indicators may effectively communicate changes in sustainable development, they may not be as effective in identifying the changes required to promote sustainable development at local levels (Mitchell 1996). Composite indicators have the potential to hide serious deficits in some sectors, which may be overshadowed by other sub-indicators, threatening the health of the system (Bossel 1999). They also have the potential to send misleading and non-robust policy messages if they are poorly constructed (Saisana & Tarantola 2002).

2.2.2 Sustainability Indicator Frameworks

Sustainability frameworks are defined sets of actions which allow sustainability to be evaluated against a set of principles (Tuazon et al. 2013). They are often specific to a particular application or broad interest groups such as an industrial sector or organisation, and form the basis of sustainability tools. There are a number of integrated sustainability indicator frameworks that are designed for application at different spatial and temporal levels, i.e. international, national, local and corporate level indicators. They include frameworks by the United Nations Commission on Sustainable Development (UNCSD), the Global Reporting Initiative (GRI), and the Institute of Chemical Engineers (IChemE) as well as those by researchers Azapagic (2004) and Labuschagne et al. (2005). An overview of relevant frameworks is provided in Appendix A.

2.3 Problem Solving and Decision-Making

Anderson et al. (2012) distinguish between problem solving and decision-making, whereby problem solving is best represented by the three steps illustrated in Figure 2-1, including the implementation and evaluation of the chosen alternative. Decision-making is defined as a process which results in a decision being made which usually encompasses the first two stages in problem solving to the point where an alternative is chosen (Anderson et al. 2012). However, implementation and monitoring (also referred to as problem resolution) is at times integrated within the decision-making process (Basson & Petrie 2001; Azapagic & Perdan 2005b; Petrie et al. 2007). This may be applicable in situations where the decision-makers are required to be involved in the implementation and monitoring of the decision outcome (Azapagic & Perdan 2005b).

The decision-making process is not linear and consists of iterations both within and between the stages, as well as the cycle as a whole (Belton & Stewart 2002). This approach can be utilised for all decision contexts, with differences in how the first two stages of the cycle are conducted and the tools required to support these (Petrie et al. 2007). Therefore, the generic decision-making process often forms the basis for the development of decision support frameworks (reviewed in section 2.3.2) which are the focus of this dissertation.

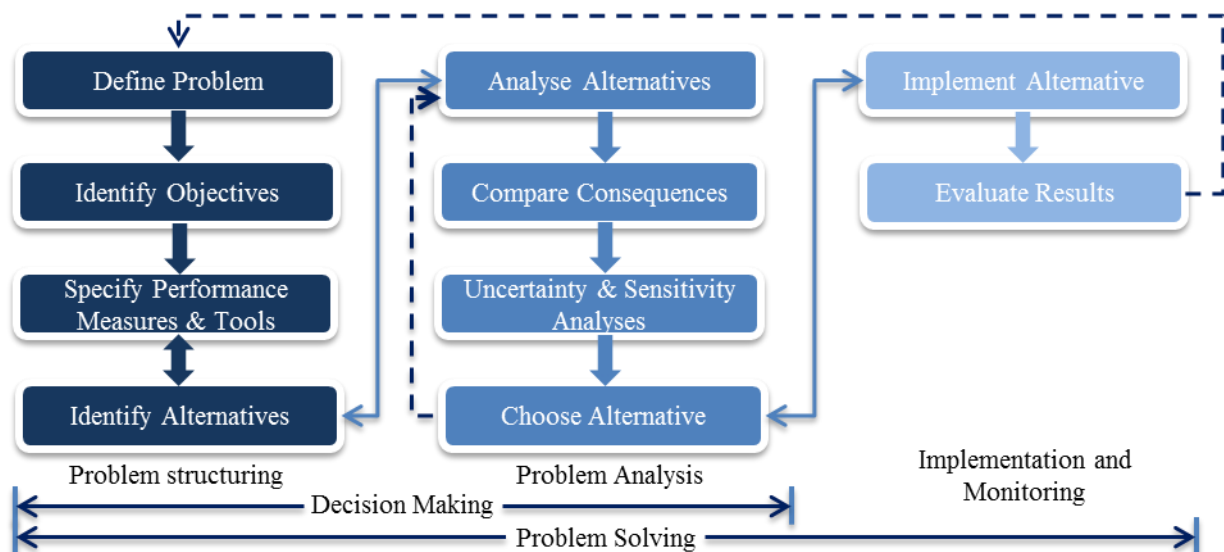


Figure 2-1: The generic decision analysis cycle adapted from Basson & Petrie (2001) including the relationship between problem solving and decision-making according to Anderson et al. (2012)

Problem structuring is the process by which an understanding of the decision situation is developed (Basson 2004). It can be described as a lengthy and deliberative process, commonly conducted via stakeholder engagement, that captures and begins to manage the complexity of the issue and how decision-makers may best move forward (Basson & Petrie 2001; Belton & Stewart 2002). The process commences with the definition of the problem at hand and the identification of clear objectives to guide the decision-making process (Azapagic & Perdan 2005a; Dodgson et al. 2009). Alternative generation and specification of performance measures are interlinked processes that can be conducted in parallel and in an iterative manner (Azapagic & Perdan 2005a). The selection of appropriate indicators, to be used in the performance assessment of alternatives, is dependent on the decision context (reviewed in section 2.3.1) which provides a challenge as to what may be considered adequate information to support decision-making (Basson & Petrie 2001; Petrie et al. 2007). Whereas, alternatives are often generated based on their ability to contribute to the specified objectives (Azapagic & Perdan 2005a; Dodgson et al. 2009). Problem structuring is based on the assumption that all relevant stakeholders will be willing to not only engage in discussions but to reach a consensus regarding problem structuring elements (Petrie et al. 2007). This stage makes it possible to capture stakeholder concerns and demonstrate that these are met by the final decision outcome (Petrie et al. 2007).

Problem analysis involves the collection of information, in terms of attributes, enabling the performance analysis of the alternatives under consideration. Multiple criteria decision analysis (discussed in section 2.3.3) is commonly employed to facilitate problem analysis, as it enables the assessment of alternatives in decision situations characterised by multiple competing criteria (Hajkowicz 2007; Ness et al. 2007). Petrie et al. (2007) suggest that emphasis should be placed on information gathering and management of uncertainty to increase robustness of decision outcomes. The management of uncertainty is typically done via sensitivity analyses which investigate whether preliminary conclusions are robust or sensitive to changes in aspects of the model (Belton & Stewart 2002). This assists in identifying key areas that must be targeted to reduce overall uncertainty improving robustness of the conclusions (Petrie et al. 2007). Uncertainty should be considered explicitly at all levels of decision-making, preventing premature elimination of alternatives at strategic or early design stages which may display better performance when defined in greater detail (Basson & Petrie 2001).

2.3.1 Decision Contexts

Decision contexts are commonly classified into three generic levels (Basson & Petrie 2001):

- i. The **strategic context**, which typically entails strategic planning (including policies and programmes) and capital investment and acquisition decisions.
- ii. The **tactical context**, including decisions made during the design and development of products, processes, technologies and services.
- iii. The **operational context**, which entails operational management (including operational purchasing and procurement) and communication and marketing decisions.

Strategic decisions are associated with longer time frames, larger spatial domains and a larger and more diverse group of stakeholders, whereas operational decisions involve shorter time frames, smaller spatial domains and a more homogenous stakeholder group (Wrisberg & Gameson 1998; Basson & Petrie 2001; Notten 2001). Strategic and tactical contexts tend to have more loosely defined scenarios/alternatives under consideration than operational decisions which are characterised by more

precisely defined alternatives. The level of definition of the alternatives has a bearing on the uncertainty associated with the different decision contexts. Uncertainty within the decision context increases from operational to strategic scenarios, due to the types of information available for the different contexts (Basson & Petrie 2001; Notten 2001; Nutt & Wilson 2010). In the strategic context, it is not possible to utilise average data making it necessary to predict relevant data. This is associated with a fair degree of uncertainty, which increases with the time horizon under consideration. Tactical studies involve less uncertainty as they may be based on technology that has already been implemented or upon which pilot studies have already been done. Operational studies involve existing systems therefore they are usually supported by high quality information which is associated with the least amount of uncertainty (Notten 2001). Direct stakeholder engagement may not be practical in all decision contexts, particularly at strategic levels and early project stages when numerous alternatives are still under being considered and the information available has considerable uncertainty (Basson & Petrie 2001; Petrie et al. 2007).

The decision context has a bearing on the type of tools and assessment criteria that are utilised. Although some work has been conducted to categorise developed indicators according to decision contexts this has been primarily focused on environmental indicators (Basson & Petrie 2001; Petrie et al. 2007). On a strategic level, it is important that decision-making activities promote sustainability, therefore it is more important that indicators that measure progress towards sustainability be utilised. In contrast, operational level indicators are more likely to be composed of transgression indicators that measure symptoms of environmental degradation (Basson & Petrie 2001). Categorisations of tools according to decision contexts have been conducted by Basson & Petrie (2001) and Ness et al. (2007). Petrie et al. (2007) provide a comprehensive categorisation of best practice frameworks within the mining and metals industry that can be used to support different stages within the decision cycle. For example, the International Council on Mining and Metals (ICMM) principles are recommended for decision framing across all three levels of decision-making.

2.3.2 Decision Support Frameworks

A decision support framework (DSF) can be considered to be management protocol that supports the framing and analysis of decision situations, providing a structured and systematic approach to complex decision-making. The generic decision-making cycle illustrated in Figure 2-1, forms an ideal basis for a DSF for sustainability in the minerals sector (Azapagic & Perdan 2005a; Petrie et al. 2007). According to Petrie et al. (2007), a meaningful DSF provides guidance on how to approach and resolve problems, leading to decision outcomes which are proactive in supporting sustainability. Therefore, it is necessary for a DSF to be well aligned with the internal decision-making processes of the various organisations and/or agencies within the sector, enabling its integration into existing processes (Petrie et al. 2007). Petrie et al. (2007) propose that the following values can be obtained from utilising a DSF within the minerals sector:

1. The structure makes it possible for an audit trail to be developed, where all elements of the decision process are recorded, ensuring that transparent and defensible decisions are taken.
2. It reduces the number of decision parameters to a smaller meaningful set which capture the decision objectives, enabling the explicit consideration and systematic exploration of risk and uncertainty.
3. A DSF allows for the consideration of both qualitative and quantitative criteria, eliminating the need for everything to be translated to a financial cost.

4. Utilising a DSF can help identify variables that play a key role in the decision outcome, and can assist in developing simple graphical tools that enable the analysis of these key variables.

The application of DSF in the minerals sector has been investigated primarily for minerals processing design (Stewart 1999; Notten 2001; Stewart et al. 2001; Basson 2004). As such the work was primarily focused on operation and tactical decision-making contexts. In 2005, Azapagic and Perdan proposed an integrated multiple criteria decision support framework, illustrated in Figure 2-2, for strategic decision-making for sustainable development in the minerals sector. The framework is underpinned by multiple criteria decision analysis (MCDA) and is designed to provide systematic guidance to decision-making in both corporate and public policy making decision situations (Azapagic & Perdan 2005a; Azapagic & Perdan 2005b). The proposed DSF is based on the generic decision-making procedure (Figure 2-1) but it explicitly includes stakeholder involvement as part of the framework, as well as the additional steps of preference elicitation and modelling prior to alternative evaluation and comparison.

Stakeholder engagement is considered to be an important and integral element of decision-making that applies legitimacy to the process (Basson & Petrie 2001; Veleva & Ellenbecker 2001; Hilson & Basu 2003; Azapagic 2004; Bell & Morse 2008). Therefore in the selection of relevant indicators for framework development, engaging stakeholders and understanding their concerns is a prerogative for sustainable development (Azapagic & Perdan 2005a). The choice of relevant stakeholder groups is dependent on the aim of the process and the extent to which a stakeholder's view is taken into account is often likely to differ according to their power to influence particular decisions (Belton & Stewart 2002; Azapagic & Perdan 2005a; Bell & Morse 2008). However, the practice of stakeholder engagement can be particularly complex with regards to how stakeholders are to be represented given that it may not be practical to include everyone (Petrie et al. 2007).

It is often useful to distinguish between decision-making situations with single or multiple decision-makers. Situations with a single decision-makers are characterised by an individual or group of stakeholder with the same preferences and objectives of a problem (Azapagic & Perdan 2005a). The shared interests decrease the likelihood of conflicts within the decision-making process. Decision-making for sustainable development commonly involves multiple decision-makers. In this case, the decision-makers commonly have different and/or conflicting preferences and objectives (Azapagic & Perdan 2005a). Distinguishing between the two situations will often be useful in anticipating the behaviour of the decision-makers during the decision-making process, enabling the facilitator to prepare accordingly.

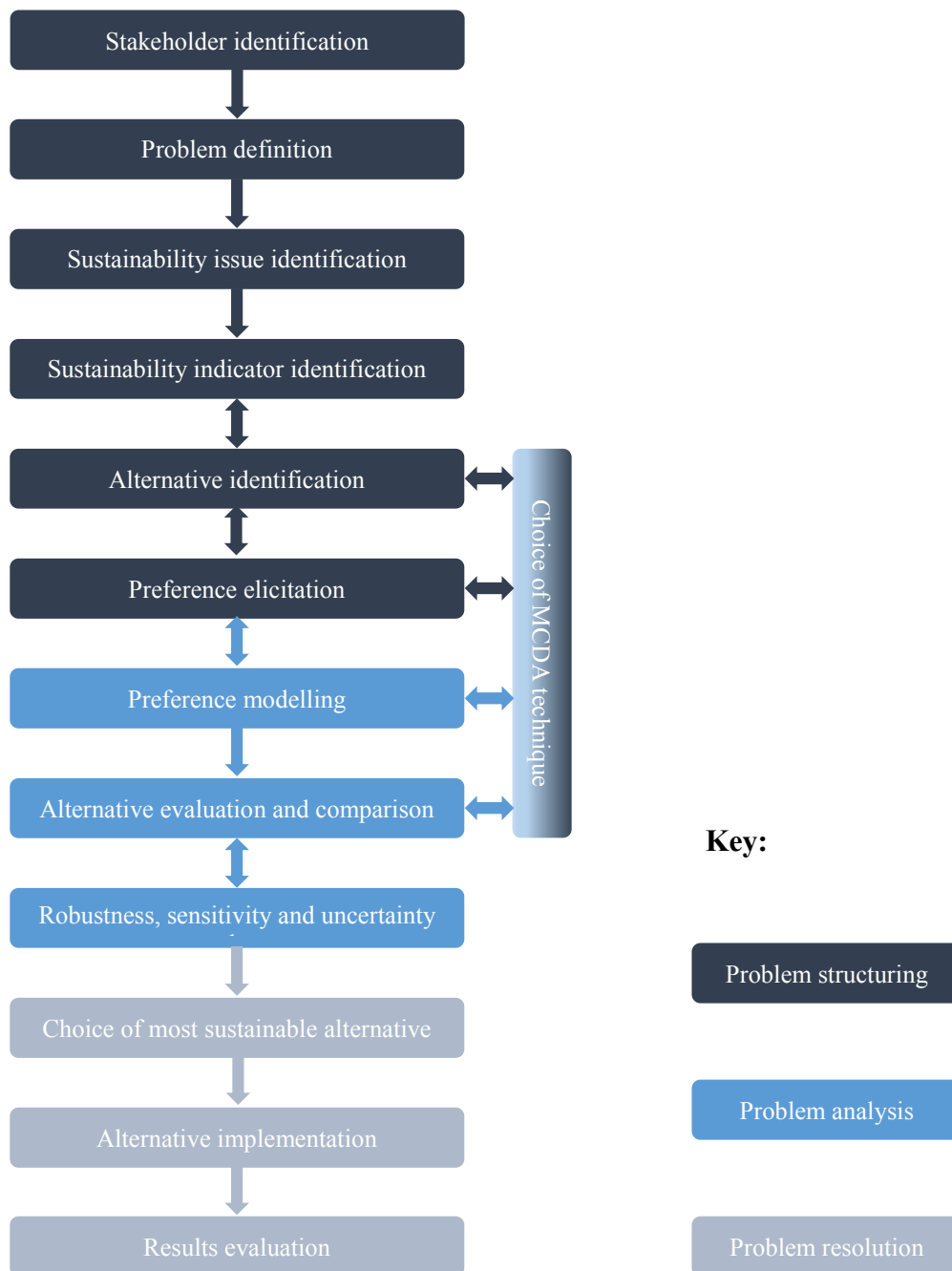


Figure 2-2: Integrated decision support framework (Azapagic & Perdan 2005b)

Alternative comparison is often carried out in terms of the decision-makers' preferences, via a process called preference modelling. Preference modelling involves the elicitation of preferences in terms of each individual criterion, describing relative importance or desirability of achieving different performance levels, and their aggregation into a model to enable identification of the most desirable alternative (Belton & Stewart 2002; Azapagic & Perdan 2005b). Therefore, modelling serves to construct a view that is consistent with the value systems of decision makers so as to accurately reflect the most preferred solution (Belton & Stewart 2002). The approach to modelling is dependent on the MCDA technique which is adopted to support the decision-making process.

There are a variety of preference elicitation techniques, with different features that impact their practical applicability. Commonly used, simple methods for eliciting criteria weights are point allocation (PA), which requires decision-makers to distribute 100 points amongst the criteria, and direct rating (DR) in which each criterion is rated on a scale of 0-100 (Riabacke et al. 2012). Research by Bottomley et al. (2000) found weights elicited by DR to be more reliable in terms of reproducibility whereas PA was found to be more cognitively demanding as decision-makers are required to keep track of how many points they have left to allocate. However, DR does not explicitly take into consideration the relative influence of different criteria on the decision-making process and is commonly employed in MCDA techniques that do not allow for compensation and trade-offs (Azapagic & Perdan 2005b). The “Max100” method explored by Bottomley & Doyle (2001) assigns the most important attribute 100 points with the rest being rated relative to it. This method was found to yield the same chosen alternative, in a multi-attribute decision-making scenario, on 91% of occasions in comparison to 87% yielded for DR (Bottomley & Doyle 2001). Preference elicitation can be conducted at different stages of the decision-making processing; prior to or after alternative identification, or iteratively before and after identification (Basson 2004). A numerical score or weight is normally used to model the relative importance of different criteria, typically on a scale from 0-1 (Azapagic & Perdan 2005b).

A short description of prominent MCDA preference elicitation techniques is provided in Appendix B.

2.3.3 Multiple Criteria Decision Analysis

Multiple Criteria Decision Analysis (MCDA) is an integrated assessment approach that enables comparison of alternatives in cases characterized by multiple objectives, uncertainty and conflicts between costs and benefits (Basson & Petrie 2001; Belton & Stewart 2002; Azapagic & Perdan 2005b). It is an umbrella term that is used to describe a collection of approaches/techniques towards the evaluation and comparison of different options. The aim of these techniques is not to provide a definite answer but to enable decision-makers’ understanding of the many facets of a problem, providing information in a succinct and comprehensible form, in order to assist to choose a preferred way forward (Belton & Stewart 2002; Hajkowicz 2007; McLellan et al. 2009). The process of MCDA is a non-linear methodology consisting of four steps (Guitouni & Martel 1998; Azapagic & Perdan 2005b):

- i. Decision problem structuring
- ii. Preference articulation and modelling
- iii. Aggregating the alternative evaluations
- iv. Making recommendations

As can be seen, the process of MCDA follows the same generic steps as the decision cycle reviewed in section 2.3, whereby steps ii. and iii. would be part of the problem analysis stage.

The performance of each alternative may be presented in the form of a performance matrix, in which each row describes an option and each column describes the option performance against each criterion (Hajkowicz 2007; Dodgson et al. 2009). Individual performance assessments are often numerical but may also be expressed as weighted scores. In cases, where no explicit trade-off between criteria is considered, this matrix may be the final product and in such cases it is normally populated using qualitative descriptions, natural units or a numerical scale such as 1-100 (Dodgson et al. 2009).

2.3.4 Choice of MCDA Techniques

The choice of MCDA techniques is dependent on the nature of the problem and the desired outcome. Azapagic & Perdan (2005) presented a set of guiding principles for method selection:

- Ease of use to non-experts
- Method logic transparency to decision-makers
- No ambiguity regarding interpretation of required inputs
- Realistic time and human resource requirements
- Ability to provide an audit trail

However, the selection of different techniques will reveal different aspects of the decision situation as well as the preferences of the stakeholders (Basson 2004). Therefore, Basson (2004) argued for the complementary use of techniques based on different assumptions. The concept of an integrating framework across the different schools of thought in MCDA is also discussed extensively by Belton & Stewart (2002). They advocated for an integrating framework that integrates methodologies through their commonalities whilst acknowledging the differences, recognizing the strengths and weaknesses of each, their appropriateness in different contexts and opportunities in which they can be complementary to each other (Belton & Stewart 2002).

A more detailed review of MCDA techniques is available in Appendix B.

2.4 Scrap Steel Recycling

Steel is the world's most recycled and reused metal, and worldwide scrap metal consumption by the steel industry has been growing by 12% per annum since 1950 (Yellishetty et al. 2011). Steel recycling has a number of potential environmental and economic benefits, including the diversion of waste from landfills as well as the promotion of sustainable natural resource management. Recycling leads to conservation of resources, by using resources released from the built environment. It accounts for significant raw material savings with 1 tonne of scrap steel saving approximately 1.2 tonnes of iron ore, 7 kg of coal and 51 kg of limestone (WSA 2009b). Metal recycling helps to minimise the ecological footprint of the industry as it "mimics a mine being continually replenished" (Yellishetty et al. 2011).

Scrap is the primary source of iron and steel in the foundry industry, and can be integrated into steel production processes to varying extents. Steel production can be split into three generic steps: raw material preparation, iron making and steel making. Three different processing routes are used for the production of carbon steel in South Africa: blast furnace/basic oxygen furnace (BF/BOF), electric arc furnace and con-arc furnace. The smelting of iron ore into pig iron via the blast furnace route is most commonly employed in South Africa, accounting for 54% of all iron produced in 2012 (SAISI 2013c). The liquid iron (pig iron) from the BF is then transported to the BOF where it is reacted with oxygen to reduce the carbon content to less than 1%, resulting in the formation of steel. The BF/BOF route predominantly uses iron ore as a raw material however scrap steel may be charged into the BOF to a maximum content of 30% (Xiarchos 2005). Direct reduced iron (DRI) is a popular alternative to the blast furnace making up 25% of iron production in 2012 (SAISI 2013c). This process involves reacting the iron ore with a reducing gas resulting in the formation of DRI, which is also known as sponge iron. Unlike the BF, this process does not require the use of coke as a reductant, avoiding the associated emissions. Of the 6.9 million tonnes of crude steel produced in 2012, 44% was via electric processing

routes. The EAF uses electricity to melt recycled scrap steel. DRI is a popular feedstock to the EAF and may be used in conjunction with scrap, depending on the availability of scrap steel and plant configuration (WSA 2009a).

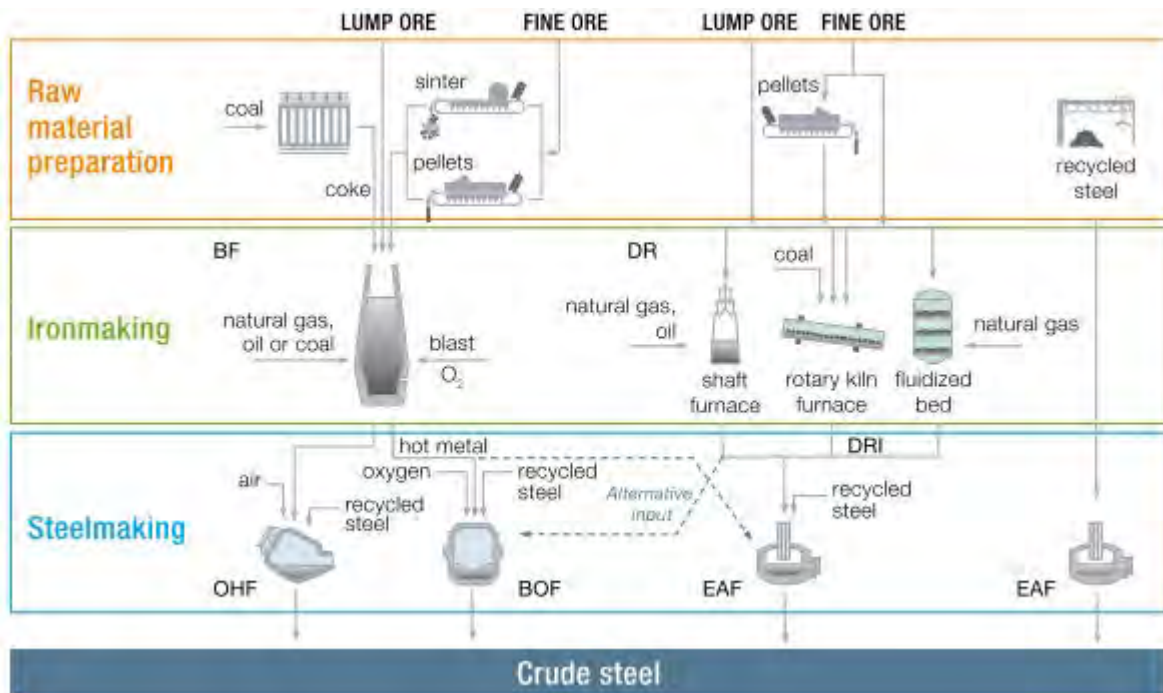


Figure 2-3: Steel production routes (WSA 2009a)

As can be seen in Table 2-4, production of secondary steel from 100% scrap metal is associated with lower energy consumption in comparison with production of primary steel via the BF/BOF or DRI/EAF routes (Grimes et al. 2008; Yellishetty et al. 2011). Approximately 72% of the energy used in primary steel production is expended during iron ore reduction in the BF, which accounts for the large differences in energy intensities (Yellishetty et al. 2011). A reduction in the energy intensity translates into a reduction in associated carbon footprint, however this is dependent on the carbon intensity of energy sources employed. In the cases of primary steel production, the overall environmental impact is dependent on the fraction of scrap steel that is integrated into the steel manufacturing process.

Table 2-4: Energy intensities and carbon footprints of different steel production routes

Steel Production Route	Energy Intensity ¹²	Carbon Footprint ³
BF/BOF	19.8 – 31.2	1.32 – 2.3
DRI/EAF	28.3 – 30.9	0.7 – 3.31
EAF	9.1 – 12.5	0.54 – 1.18

¹ Source: (Grimes et al. 2008; Yellishetty et al. 2011)

² Some studies report lower values for EAF energy consumption, ranging from 2.1 – 4.3 GJ/t steel (Worrell et al. 2008; Fruehan 2009). The BRI report attributed this discrepancy to the different energy efficiencies that are used when calculating the overall energy consumption (STI 2010).

³ Source: (Grimes et al. 2008)

2.4.1 Limiting factors in recycling

Despite the environmental benefits provided by scrap metal recycling, its economic feasibility remains a major driver (Yellishetty et al. 2011; UNEP 2013). Metal scrap recycling has a number of potential economic benefits, including revenues from valuable and scarce metals that might have been lost and reduced processing costs linked to reduced energy consumption (Yellishetty et al. 2011; UNEP 2013). In a report on the opportunities and limits in metal recycling, UNEP (2013) suggested that the economic success of metal recycling is based on the following:

- Supply and demand of metals and the resulting monetary value
- Processing technologies employed, including economies of scale
- Impact of policies on activities associated with the recycling chain

The value of the recycled metals is dependent on purity, which is informed by its initial use (design), liberation and sorting efficiency and recycling routes (UNEP 2013). The initial use of the metals determines its chemical reactivity and the degree of treatment required to remove residual alloying elements (Yellishetty et al. 2011). There are over 5000 different steel alloys, each with different compositions, which all have different chemical, physical and environmental properties (UNEP 2013). The identification and sorting of the different grades, according to concentrations of residual elements is a critical step in steel recycling as this will affect the properties of the final steel product (Muchová & Eder 2010; Yellishetty et al. 2011). For example, presence of copper, tin and antimony in steel pose a great challenge in the production of high-quality steel due to their chemical and thermodynamic properties (UNEP 2013). In some cases, the treatment costs become a major financial barrier, making primary steel production a more cost-effective option particular in the manufacture of special steel products that require no or low residual elements (Yellishetty et al. 2011; UNEP 2013). Therefore, the success of secondary metal markets is largely dependent on the ability to retrieve and refine metals embedded in disused structures, post-consumer waste and other waste streams, at a price that is competitive with primary markets (Yellishetty et al. 2011).

2.5 Concluding Remarks

As shown in section 2.1, there is growing awareness of the importance of sustainable development within the minerals sector and on a strategic level within organisations and governments. Whilst mining and beneficiation companies may have translated sustainable development principles into practice, the measurement and assessment of sustainability in strategic inter-actor contexts remains a challenge. Although a multitude of indicator frameworks have been developed within the minerals sector (reviewed in Appendix A), the majority of frameworks are targeted towards mining activities limiting their applicability to sustainability assessments in downstream beneficiation. Furthermore, the majority of these have been targeted towards existing operations, limiting their applicability in strategic planning such as policy development.

Decision-making is a complex process, in which gaining an understanding of the decision situation is an important step before any analysis can be undertaken. The decision situation will have an impact on the criteria and tools used in the evaluation of different alternatives. Stakeholder consultation is an integral part of decision-making, throughout the process, to ensure that taken decisions are transparent and defensible. Stakeholder engagement also ensures that the decisions taken are in line with the preference and value systems of the decision-makers. Decision support frameworks provide a structured

and systematic approach to decision-making in complex situations, potentially leading to outcomes which serve to promote sustainable development. The structured approach, which encourages stakeholder engagement, makes it possible for the different elements of the process to be recorded, ensuring that all decisions are transparent and defensible.

Chapter 3 Research Methodology

The literature review shows the complexities associated with decision-making for sustainable development in the minerals sector, particularly when it comes to downstream mineral beneficiation. Decision support frameworks (DSFs) are advocated as providing a structured and systematic approach to decision-making, and this dissertation investigates the applicability of DSFs to support the evaluation and selection of mineral beneficiation options according to their sustainability performance.

This chapter begins with an outline of the research questions which guided this study, and presentation of the research approach. The generic DSF that is investigated is then presented, followed by a description of the research methods employed.

3.1 Research Questions

In the minerals sector, decision-makers may be confronted with a variety of decision situations. These decisions are often interlinked, and may be illustrated in a nested format, as in Figure 3-1, whereby the area of focus becomes more constrained as one progresses from resource analysis to opportunity analysis. In the context of this dissertation, the South African minerals beneficiation strategy identified ten strategic commodities, from which five value chains were selected as having the greatest potential for value addition through beneficiation (DMR 2011). Based on the identified value chains, the KZN Project conducted value chain analyses which resulted in the identification of key opportunities for stimulating sustainable downstream mineral beneficiation. The analysis of the iron and steel value chain yielded a number of opportunities, including the potential for increased local beneficiation of scrap steel (Cohen & Notten 2015). In comparison to the range of decisions that may be explored, the analysis of the opportunity presented by scrap steel has a relatively constrained scope. The scope directly impacts the decision situation, including the number of alternatives under consideration as well as the number of stakeholders.

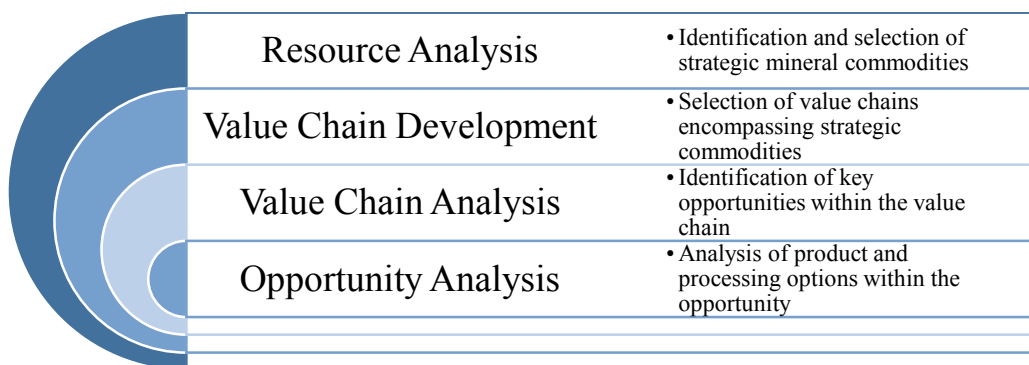


Figure 3-1: Examples of different decision situations that exist in the context of mineral beneficiation

Although the research approach applies a DSF on the opportunity presented by scrap steel for increased local beneficiation, this dissertation considers more broadly the applicability of DSFs across the range of potential decisions pertaining to mineral beneficiation. Hence, the following research question was formulated:

1. *What could be learnt from applying a decision support framework on a constrained sub-sector that could possibly be applied to other sectors or on a larger scale?*

In order to promote and support sustainable mineral beneficiation it is often necessary for governments to develop strategies and policies. However, the success of these policies is not guaranteed, as was shown in the case of Zimbabwe in section 1.1.2. As discussed in section 2.3.2, decision support frameworks have been recommended for policy development in the minerals sector (Azapagic & Perdan 2005a). The second research question investigates this recommendation:

2. *Would the application of a decision support framework be beneficial in the development of a mineral beneficiation strategy?*

The structure of DSFs enables alternatives to be compared according to their sustainability performance whilst taking into consideration the preferences of decision-makers. Sustainability performance assessment is dependent on the identification and investigation of a set of key indicators, which are based on relevant sustainability issues in the decision situation. However, the comparison of alternatives, and subsequent choice of alternative, is inherently influenced by the value systems of the decision makers. Hence it is important to gain an understanding of the preferences of different stakeholders when it comes to the question of increased local beneficiation of scrap vs its exportation. As such, it was necessary for the following sub-set of questions to be investigated:

- a) What are the key sustainability issues in the decision situation?
- b) What are the relative influences of different indicators on decision-making?
- c) What are the potential impacts of stakeholder value systems on the decision-making process?

3.2 Research Approach

As introduced in section 1.3, this dissertation aims to investigate the applicability of DSFs for strategic planning in the minerals sector. To do this, a generic DSF (presented in section 3.3) is applied to the opportunity presented by the iron and steel scrap industry for increased local beneficiation. More specifically this entails the development of an indicator framework to support the evaluation of mineral beneficiation options according to their sustainability performance as well as exploring the different factors that affect decision-making from a stakeholder perspective. The approach takes into consideration a number of key factors, namely the decision context, data quality, alternative generation, evaluation criteria relating to technical, environmental, economic and socio-political aspects, as well as tools for both performance assessment and decision support.

3.3 Decision Support Framework

The decision support framework developed in this dissertation is structured similarly to the DSF by Azapagic & Perdan (2005), reviewed in Chapter 2, according to the illustration in Figure 3-2. The study was conducted in three stages beginning with problem structuring (discussed in section 3.4 and with results in Chapter 4), which entails problem definition and identification of alternatives and key sustainability issues. This was followed by problem analysis (discussed in section 3.5), which was split into two stages; preference elicitation which explores stakeholder value systems and alternative evaluation and comparison, the results of which are presented in Chapter 5 and Chapter 6 respectively. The specific methods used in each of the steps are presented in sections 3.3 to 3.4.

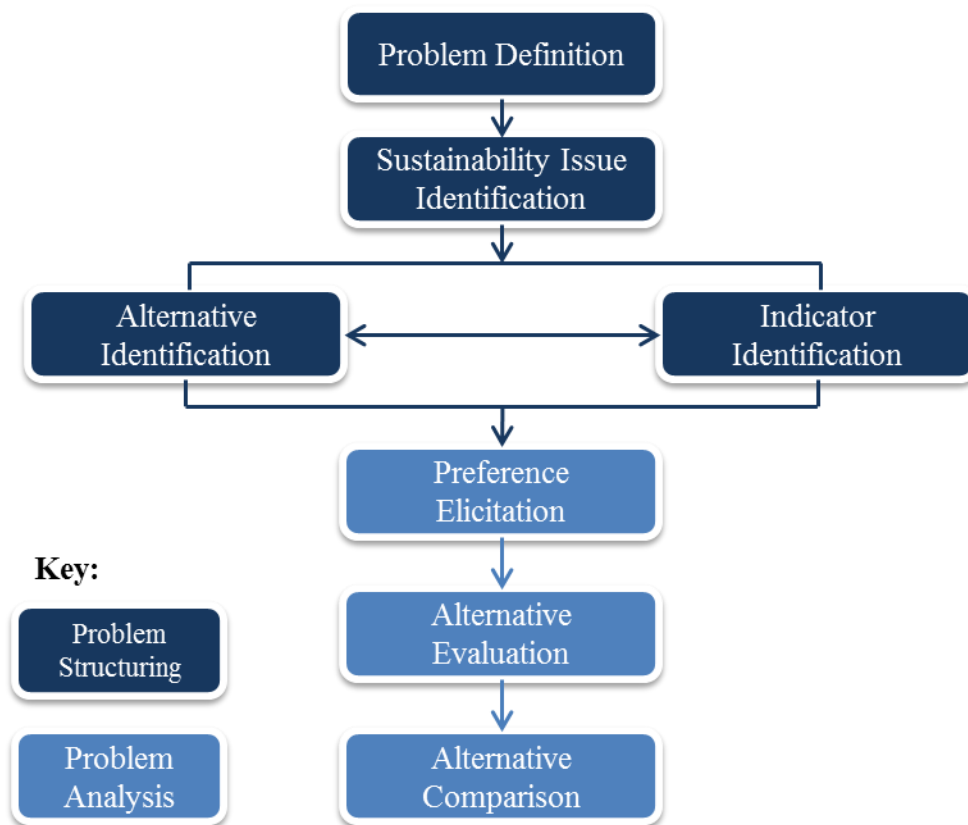


Figure 3-2: Decision support framework developed in this research (adapted from Azapagic & Perdan, 2005a)

As the objective of this study is on investigating the applicability of decision-support frameworks for strategic decision-making, more emphasis is placed on the actual steps outlined in the DSF rather than the final outcome of the decision-making process. This enables the evaluation of what could possibly be learned from applying a DSF on a constrained sub-sector, which could be applied on a larger scale.

Although the framework by Azapagic & Perdan (2005) is underpinned by MCDA (as discussed in section 2.3.2), this study does not explore the different techniques available. The integration of MCDA techniques would have greatly complicated the study and detracted from the purpose of the study. Ultimately the study is focused on the application of DSFs in general and not on the selection and application of MCDA techniques, which could be considered to be a variable in DSFs. Therefore, the methodology does not include preference modelling, which is dependent upon the selection and application of an MCDA technique.

3.4 Problem Structuring

3.4.1 Problem definition

Background research into the South African iron and steel scrap industry was conducted in order to contextualise the case study. The outcomes of this review included the definition of the problem, followed by the specification of the decision objective. Therefore this stage served to further define and elaborate on the types of decisions that need to be made, and the boundaries of the system under examination.

3.4.2 Identification of sustainability issues

The identification of sustainability issues currently being faced by the industry was based on desktop research into the industry as well as engagement with relevant stakeholders. The stakeholder engagement process took the form of semi-structured interviews. The desktop research took into consideration issues highlighted in literature as well as those relevant to national development strategies and policies.

3.4.3 Identification of key sustainability indicators

A combination of top-down and bottom-up approaches was utilised in the indicator framework development, whereby the approach was objective led whilst integrating multi-stakeholder engagement as a crucial element in the SDI selection process. An indicator set was generated by linking the sustainability issues to indicators as well as by ensuring headline indicators that are recurrent across frameworks reviewed in literature are represented. It was necessary for some of the issues to be disaggregated into lower level criteria; for example, climate change was disaggregated into air emissions that contribute to climate change.

The final set of indicators was legitimised through:

- i. engagement with relevant stakeholders to ascertain the relevance of the proposed indicator set
- ii. benchmarking with already published relevant sustainability reports to ensure that none of the opposition to proposed indicators was motivated by opportunistic behaviour on the part of the stakeholder

3.4.4 Alternative identification

As the identification of indicators and alternatives are interlinked, these steps were conducted in parallel and in an iterative manner. This was based on the current status quo within the industry as well as outcomes from the KZN Project tasks.

3.5 Problem Analysis

The problem analysis stage entailed the evaluation of alternatives and exploring stakeholder value systems.

3.5.1 Preference elicitation

Preference elicitation was conducted in order to investigate the relative importance placed on each criterion by the different stakeholders. The elicitation method employed took into consideration the time available for the exercise, the cognitive demand on the user as well as its reproducibility. Therefore the “Max100” preference elicitation method (Bottomley & Doyle 2001) was chosen whereby stakeholders were required to rate and assign relative weights to the sustainability criteria identified in the problem structuring phase. The most important criterion was assigned 100 points and the rest of the criteria assigned points relative to the most important one. The results of the scoring exercise were then normalised to sum to 1, in order to ascertain the relative influence.

3.5.2 Evaluation of alternatives

Each of the alternatives was evaluated according to their performance in the different criteria identified during the problem structuring stage. The performance was evaluated for the year 2013, as this was the

most recent year for which industry data could be obtained at the time the research was conducted. These data were also considered to provide an accurate representation of the state of the industry in the context of the current debate surrounding the fate of scrap metal. In cases where industry data were not available for that year, estimates were based on the most recent data. Literature data were used in cases where no industry data was available. The definition of system boundaries was based on an analysis of the decision situation (section 4.3), whereby the alternatives were identified. Therefore, the system boundaries under consideration are presented in section 4.5.1. Details of all assumptions made as well as data sources are available in Appendix H.

The sustainability performances of the alternatives were then presented in the form of a performance matrix, in accordance with MCDA practices.

3.5.3 Comparison of alternatives

The alternatives were compared according to their sustainability performance, presented in the performance matrix. The value systems of the stakeholders, ascertained during the preference elicitation phase, were also taken into consideration during the comparison. More specifically, the potential impacts of stakeholder perspectives on the decision-making process.

3.6 Data Collection Methods

Data collection was conducted using a combination of both primary and secondary sourcing. The problem structuring stage was approached as a desktop study whereby secondary data sourcing was the primary mode of data collection. Secondary sourcing was also employed in the evaluation of alternatives according to their sustainability performance.

Primary data collection took the form of interviews with relevant stakeholders. The interviews served to provide an understanding of the current state of the industry as well as any challenges, threats and opportunities that exist. They also served to validate the results of the problem structuring phase, particularly the identification of key sustainability issues and ultimately indicators. The interviews gave stakeholders the opportunity to voice their opinion on the level of interaction between different industry players as well as their perspective on the future of the industry. A set of questions was compiled in the form of a questionnaire which was used in a semi-structured format during the interview process. The majority of interviews were conducted face-to-face which allowed for further interaction and questioning of rationale behind responses. In cases where face-to-face interviews were not possible a combination of email and telephonic correspondence was used. Audio recordings of each of the interviews were made, which lasted for approximately 60 minutes, and were later transcribed. The interviews were conducted at the participants' location of choice. The preference elicitation exercise was included as part of the interview and was conducted at the end. Including the exercise at the end of the interview ensured that the exercise was fully contextualised as the stakeholders had been afforded the opportunity to explore and discuss the sustainability issues being faced by the industry.

The full questionnaires used in the interviews are available in Appendix C.

3.7 Research Ethics

To ensure that the research complied with ethical practices, it underwent an ethics review by the Engineering and Built Environment Ethics in Research Committee (EiRC) prior to data collection.

Subsequently, the proposed research was found to be compliant with the ethical standards and approval was granted by the EiRC. A copy of the form is available in Appendix D.

Before the commencement of any interviews, a participant was requested to sign an informed consent form. The consent form (available in Appendix C) ensured that each of the participants was clear on the objectives of the study and understood the procedures regarding confidentiality. It also allowed for audio recording of the interviews. No direct reference to the participants is made in the results chapters, instead, evidence is presented in an anonymised form. As some of the information shared in the interviews may indirectly reveal the identity of participants, summarised forms of the interviews (instead of transcripts) have been made available in Appendix E. A copy of the interview summary was made available to each participant for review, with the condition that they will only be published with their approval.

Chapter 4 Case Study: South African Iron and Steel Scrap Industry

The results of the problem structuring stage, discussed in section 3.4, are presented in this chapter. It begins with a background on the South African iron and steel industry. This is followed by a review of the current status quo in the ferrous scrap metal industry in South Africa, which serves to contextualise the study and provide an understanding of the decision situation. Based on this review, section 4.3 further defines the problem and objectives of the decision-making process. This includes identification of the alternatives under consideration. The chapter concludes with the identification of key sustainability issues, which informs the development of an indicator framework against which the alternatives are evaluated (the results of which are presented in 5.4). This was based on desktop research into the industry and legitimised through stakeholder engagement, with the full results of the latter presented in Chapter 5.

4.1 Background to the South African Iron and Steel Industry

South Africa has a large and well-established iron and steel sector which is based on the presence of large domestic reserves of iron ore. In 2012, South Africa was the 7th largest iron ore miner globally with 67.1 million tonnes, of which 85% was exported unprocessed.

Table 4-1: Overview of iron ore and steel production in South Africa in 2012

IRON ORE	Tonnes	Source
Iron ore production	67 100 000	(DMR 2012)
Total iron ore sales	65 500 000	(DMR 2012)
Iron ore export sales	57 100 000	(DMR 2012)
Iron ore local sales	8 390 000	(DMR 2012)
STEEL	Tonnes	Source
Total crude steel production	6 940 000	(SAISI 2013c)
Exports of primary steel products	2 070 000	(SAISI 2013a)
Imports of primary steel products	941 000	(SAISI 2013b)

Iron and steel has been identified as one of five value chains which the South African government believes have the greatest potential for value addition through beneficiation (DMR 2011). Therefore, supporting and growing the industry – with a particular focus on the sustainable promotion of downstream beneficiation – is a key government priority. Iron and steel is of interest not only due to the variety of beneficiation opportunities it provides, but the sector also requires feedstocks that include a number of strategic commodities including chromium, manganese and vanadium, as identified by the DMR (2011)⁴. In addition, there are a range of potential processing routes. Steel has multiple applications in a wide variety of manufacturing sectors, including building and construction, packaging and mining, resulting in a broad range of beneficiation opportunities. Furthermore, the iron and steel value chain presents strong opportunities for recycling at the end of products' service life, with scrap steel serving as an input to the electric arc furnace steel production process. As such the value chain presents a number of opportunities for potential growth.

⁴ The South African mineral beneficiation strategy outlines ten strategic mineral commodities, from which five value chains are selected in order to indicate the value in promoting beneficiation for the identified commodities (DMR 2011).

4.1.1 Value chain description

The iron and steel value chain consists of four distinct beneficiation stages starting with the production of iron ore pellets and lump ore and ending with the formation of fabricated steel products.

Table 4-2: Iron and steel value chain mineral beneficiation stages (adapted from Anglo American 2011)

Stage	Process Description	Products
1	Mining of raw iron ore followed by the production of a saleable product	Iron ore pellets; Lump ore
2	Conversion of iron ore into pig iron or liquid iron, followed by refining and shaping into primary steel products	Ingots; Blooms; Billets; Slabs
3	Fabrication of semi-finished products for sale to manufacturing industries or direct use in applications such as construction	Wires and Cables; Tubes and Pipes; Plates and Sheets
4	Production of end products	Automotive; Machinery and Equipment; Packaging;

The majority of primary steel manufactured domestically is converted to semi-finished products with 98.4% converted in 2012 (SAISI 2013a). Of the semi-finished products manufactured in 2013, 71% were sold domestically in South Africa. In South Africa semi-fabrication is commonly carried out by primary steel manufacturers (AMSA 2014c; EVRAZ 2014; Scaw 2014). Semi-finished products can be converted into a wide variety of end-use products including beverage cans, hardware products and panels for the automotive sector or they may be used directly mainly in the construction sector.

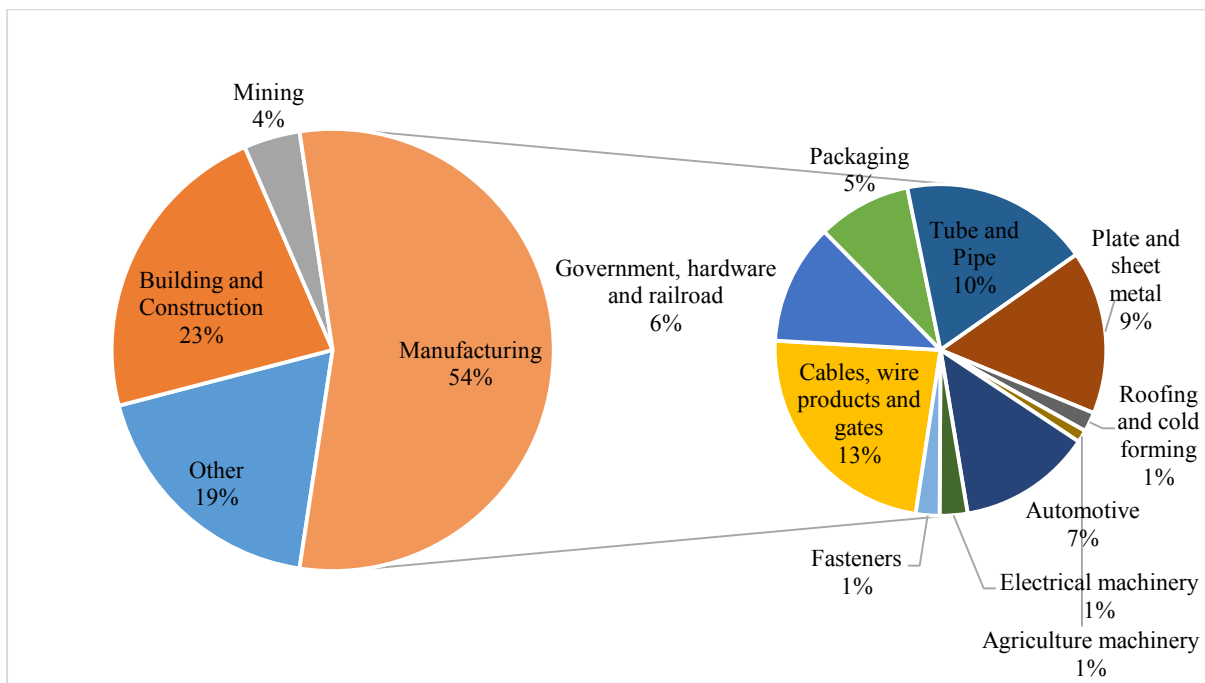


Figure 4-1: South African domestic steel market share for the first half of 2011 (AMSA 2011)

From 2003, there has been a steady increase in the percentage of domestic steel consumption that has been met by imports, whereas overall consumption has fluctuated (illustrated in Figure 4-2). As shown

in Figure 4-2, from 2003 to 2013, imports increased from 5% to 25%. Volatility in the South African steel industry has been attributed to a number of factors including technical problems, lack of a secure energy supply as well as protracted strikes in the metals and engineering sectors (SAISI, personal communication 2015, May 15). Increased imports may also be attributed to the worldwide excess steel capacity, resulting in cheaper exports (e.g. from China) entering the local market.

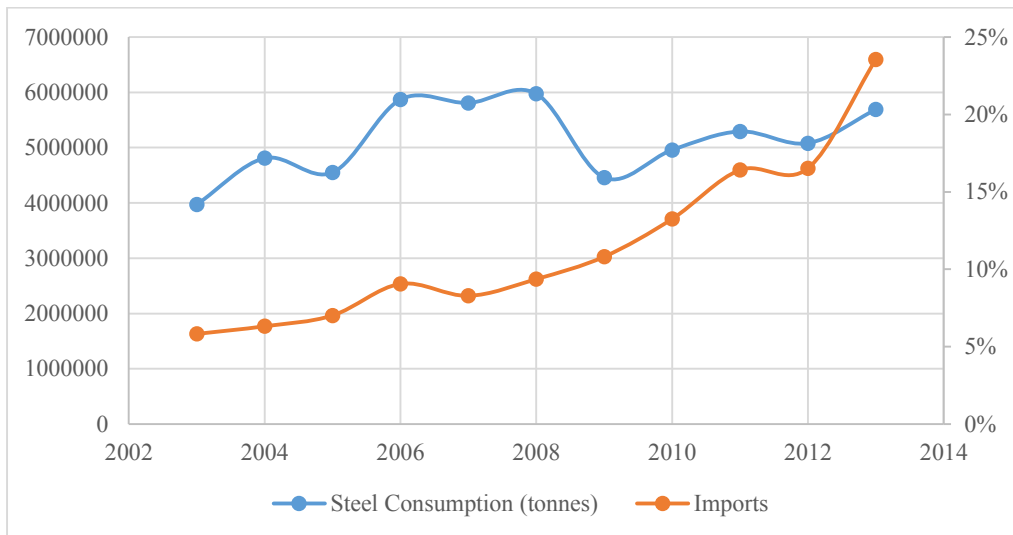


Figure 4-2: Steel consumption and imports in South Africa (SAISI 2015f)

4.1.2 Foundries

Foundries produce a wide range of cast products that would be difficult and/or uneconomical to produce via other routes due to their complex shapes and material specifications. Castings are made through melting of scrap metal and/or metal ingots, and pouring or injecting the molten metal into moulds. Cast products are manufactured for a wide range of sectors, including mining, construction and general engineering, as shown in Figure 4-3.

More details regarding the current state of the foundry industry are provided in section 4.2.2.

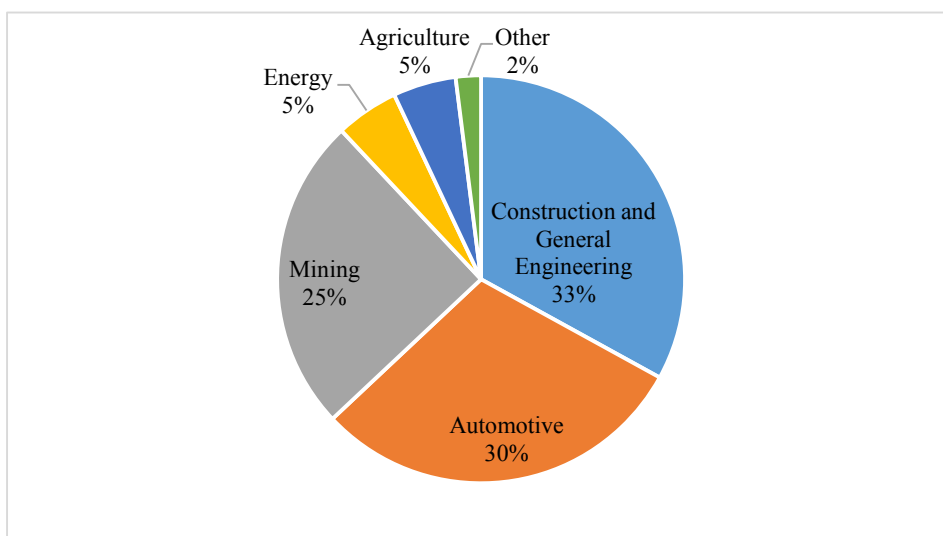


Figure 4-3: South African foundry industry markets (Davies 2015)

4.2 Ferrous Scrap Recycling in South Africa

In South Africa, ferrous scrap metal accounts for 90% of all metal scrap traded, both for export and local beneficiation (Conningarth Economists 2013). In 2011, approximately 40% of all ferrous scrap was exported with a value of R 4.6 billion (Conningarth Economists 2013). Of the remaining scrap, the majority was beneficiated in primary steel mills whilst the rest was processed in foundries. The scrap metal industry not only contributes to value-addition and employment, but scrap consuming industries also manufacture intermediate products for downstream sectors leading to greater value-addition and employment creation (DED 2013). In 2011, the foundry and scrap metal industry contributed R 24 billion to national gross domestic product (GDP) with a total of 28 484 direct employees (Conningarth Economists 2013).

4.2.1 Scrap steel value chain

Scrap steel is handled by a number of key players throughout its value chain, as illustrated in Figure 4-4. There are a number of potential sources of scrap steel which can be broadly classified into three categories (Yellishetty et al. 2011):

- **Home scrap** which is internally generated in steel mills and foundries. This scrap is often of a very high quality is quickly recycled back into the process as the alloy characteristics are known.
- **New scrap** which is generated in downstream manufacturing plants.
- **Obsolete scrap** which is produced at the products' end of life. It has a wide variety of chemical and physical characteristics therefore requires significant preparation prior to reprocessing into recycled steel.

New scrap is generated as a by-product of manufacturing industries (e.g. automotive) in the form of off-cuts and scrapped material (Conningarth Economists 2013). It is generally of a higher quality and is sold directly to scrap recyclers. Obsolete scrap is a major source of scrap metal in the South African foundry and scrap metal industry, accounting for almost 60% of all scrap generated in 2011 (Conningarth Economists 2013). Obsolete scrap resultant from industrial decommissioning sources is often purchased directly by scrap recyclers. In contrast, scrap discarded by the general public is commonly collected by informal collectors which include individuals who collect scrap and sell it onto scrap recyclers or small businesses which buy scrap from individual collectors. These small businesses often have the capability to weigh and clean scrap before selling it to scrap recyclers. Scrap recyclers can be broadly categorised into two groups: scrap merchants and scrap processors. Scrap merchants engage in preliminary sorting and partial processing of scrap before selling it to major recyclers who process the scrap more thoroughly before exporting or selling it to scrap consumers. In South Africa, scrap processors extensively process the scrap to the required specifications for beneficiation by downstream industries. Vertical links commonly occur within the industry whereby relationships are formed between different players in a supply chain. Formation of these relationships is commonly as a result of the need to ensure security of a steady supply of good quality material, particularly between scrap metal recyclers and consumers (Econex 2008). Stakeholders may also play more than one role in the value chain, whereby an integrated value chain is formed from metal recycling to beneficiation. For example, a foundry may find it beneficial to own a scrap metal recycling company, so as to ensure a reliable supply of raw materials for further beneficiation.

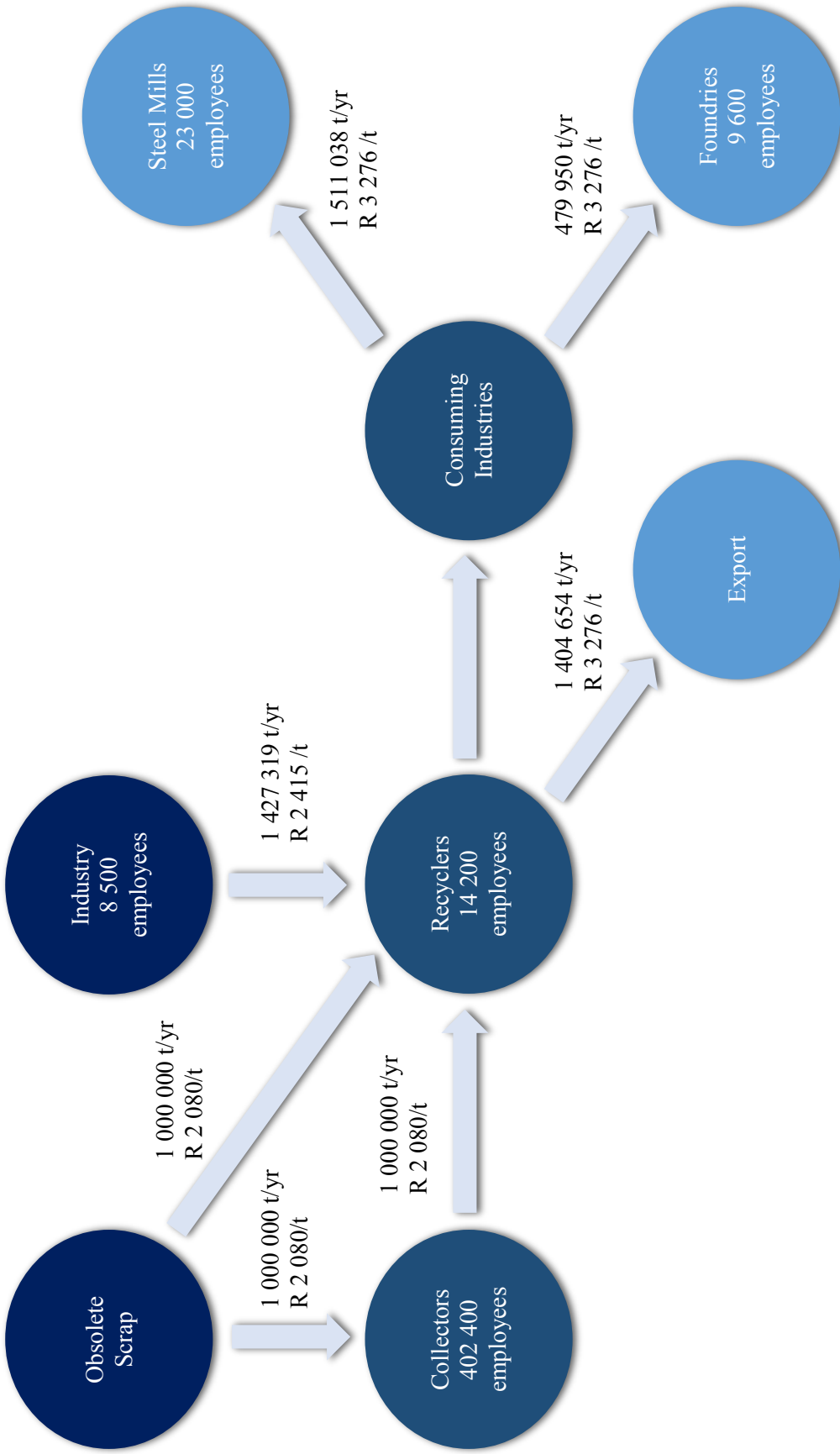


Figure 4-4: South African scrap steel industry value chain map including steel flows and value at each stage, in 2011 (Conningarth Economists 2013)

4.2.2 Local beneficiation vs export of scrap metal

The export of scrap metal has been identified as a significant concern to some in the iron and steel industry, as it is viewed to come at the expense of local beneficiation, hampering access to affordable and quality scrap metal for local scrap processors (Conningarth Economists 2013; DED 2013; Moodley 2014; Khumalo 2013). In recent years, there has been a decline in the South African scrap consuming industry which has been attributed to higher costs of scrap metal due to rising exports (DED 2013). During the period 2001 to 2011, a correlation between scrap exports and international prices was exhibited whereby from 2001 to 2011 the average price of ferrous scrap increased by 18% per annum with a corresponding increase in export volumes of 11%. A study conducted by Econex (2008) supported the notion that domestic scrap prices are determined in the international scrap metal market. Local consumers effectively pay export parity prices which take into consideration the different logistical requirements (MRA 2008).

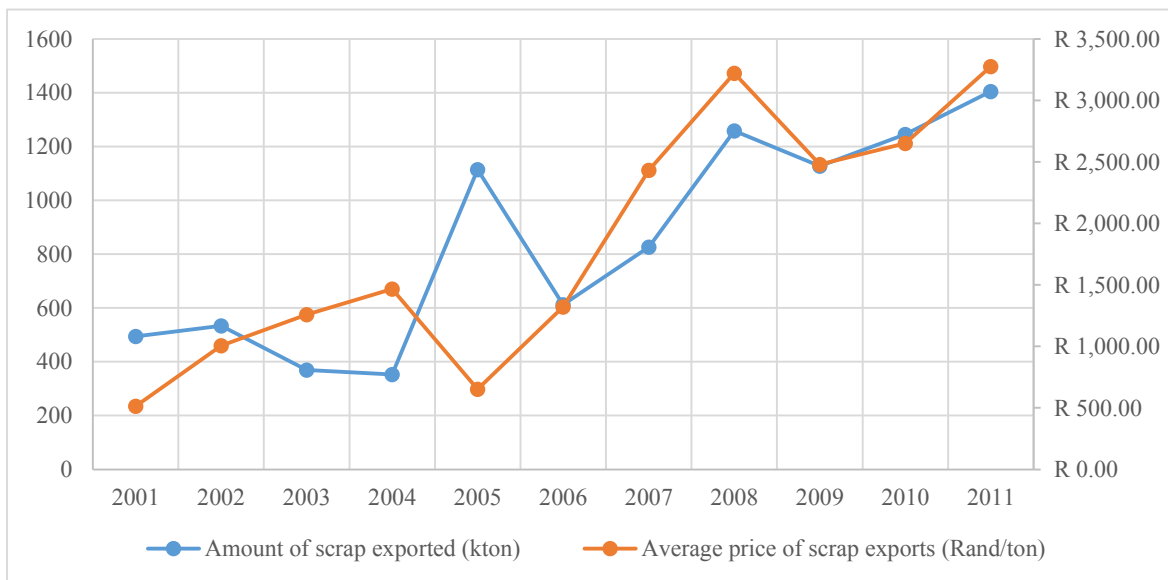


Figure 4-5: Ferrous scrap metal export volumes and international prices from 2001 – 2011 (Conningarth Economists 2013)

Rising international prices have been attributed as the main cost driver for increasing exports (DED 2013). However, the assumption that export volumes are driven by market prices has been disputed by the Metal Recyclers Association of South Africa (MRA), instead attributing rising exports to a number of factors (MRA 2008). According to the MRA (2008), the majority of scrap generated and processed in coastal regions is exported due to a combination of a relatively low concentration of consumers in the area, and the logistics associated with transporting the scrap inland where the major consumers are located. The local consumption of scrap is also affected by the grade (i.e. quality) of the scrap available. Therefore, a large proportion of scrap destined for the export market is reportedly comprised of “low” grades that are considered unsuitable for domestic consumption (MRA 2008). This is due to the physical and chemical composition of the scrap, as well as the presence of impurities such as paint, which will not only affect process efficiency but may not be suitable for the technology being employed.

Increased exports have also been linked to reduced availability of local scrap availability, and have allegedly “deprived” local scrap consumers of essential inputs to their processes (DED 2013). Between 2007 and 2011, there was a 70% increase in steel scrap metal exports whilst a 15% decrease in foundry

outputs was observed (Conningarth Economists 2013). The foundry industry also recorded a 30% decrease in employment in foundries during the same period (DED 2013). However, the decline in the industry has been attributed to a myriad of sustainability issues including challenges pertaining to increasing energy costs, labour productivity skills availability and access and competitiveness in the global market (Davies 2015).

In 2013 the South African government implemented a policy directive to regulate exportation of scrap metal with the ultimate goal of ensuring a steady supply of reasonably priced, good quality scrap metal to local industries in the hopes of increasing capacity and competitiveness (DED 2013; DTI 2013). The growth of the scrap industry would also contribute to various governmental policies to promote local content and resuscitate value-adding manufacturing capacity (DED 2013). The policy directive stipulates that scrap metal may only be exported after it has been offered to domestic consumers for local beneficiation, at a preferential price 20% lower than international prices⁵. Under the directive, all export permit applications will be circulated for 15 working days by the International Trade Administration Commission (ITAC) of South Africa, during which local consumers will have the opportunity to express an interest in purchasing the scrap (DTI 2013). If at the end of the circulation period no purchase agreement has been signed, an export permit will be issued by ITAC. The directive has been met with mixed reviews, throughout the scrap metal industry. The preferential pricing system has been reported as ineffective by beneficiators with allegations that scrap metal recyclers are reportedly circumventing the regulations (Steyn 2014; Creamer 2014). Whereas, scrap metal recyclers reported a decrease in sales citing lack of cooperation from local consumers, when it comes to payment terms, and delays in the issuing of export permits (Williams 2014; Steyn 2014).

4.3 Decision Situation

The scrap metal industry poses a number of options as to the fate of recycled materials. As such decision makers are faced with the question of which option for scrap metal processing has the most potential sustainability benefits. As illustrated in the ferrous scrap value chain presented in Figure 4-4, there are three main options regarding the fate of recycled metals; they can either be exported or beneficiated locally in steel mills or foundries. Global demand for scrap steel makes exportation of recycled scrap steel an attractive option for scrap merchants. However, as stated in the previous section, it may be viewed to come at the expense of local beneficiation. Alternatively, scrap steel can be integrated into steel production processes to various extents, dependent on the processing route being employed. Foundries are dependent on scrap as the primary source of iron and steel, presenting an alternate option for further local beneficiation of scrap steel. Therefore the alternatives under consideration are as follows:

- Exportation of recycled scrap steel
- Further beneficiation in steel mills
- Further beneficiation in foundries

The decision situation can be characterised as one with multiple decision-makers. Although institutional stakeholders (i.e. government) may wish to drive their own preferred alternative through policy

⁵ The preferential pricing system provides local consumers with a 20% discount on “Spot Market Prices” as reflected on www.scrapindex.com (DTI 2013). These prices are calculated by ITAC monthly and displayed on the ITAC website.

development, such decisions would require the buy in of relevant stakeholders in the scrap metal industry.

4.4 Key Sustainability Issues

The iron and steel industry faces a number of sustainability challenges, threats and opportunities which were used to inform the identification of key sustainability issues, shown in Table 4-3. The identification of key sustainability issues were based on literature as well as background research on the status quo in the industry, which included drawing from government sources and industry publications. Each of issues can be categorised according to the different dimensions of sustainable development. As can be seen from Table 4-3, all of the issues can be viewed from an economic perspective. However, not all measures can be monetised and instead can be represented by proxy economic indicators which may not be an accurate representation of the resultant impacts. For example, climate change can be expressed in monetary terms through the costs associated with emission of greenhouse gases, however this does not fully encapsulate the long term and widespread effects of climate change. The role of the stakeholders also impacts their perspective on similar issues. For example, when it comes to the matter of employment, the government may be more concerned with the promotion of labour intensive industries, whereas industry players may place more emphasis on labour costs.

Table 4-3: Key sustainability issues in the iron and steel industry

Aspect	Key sustainability issues	Economic	Environmental	Social
Access to raw materials	Access to raw materials			
Contribution to economic development	Contribution to GDP			
	Contribution to balance of payments			
Economic performance	Production costs			
	Profitability			
	Value addition			
	Market risk			
Energy	Energy			
Environmental performance	Water management			
	Air pollution and climate change			
	Waste production			
Socio-economic performance	Contribution to employment			
	Skills availability			

4.4.1 Access to raw materials

Access to raw materials and inputs, at a competitive price, for local beneficiation is a key constraint as it threatens production volumes and the immediate survival of the industry (DMR 2011; SDSN Thematic Group 10 2013; Turok 2013). International price determination of raw and intermediate materials, which is influenced by supply and demand, does not take into consideration production proximity. Therefore, local manufacturers are often required to pay import parity prices for inputs irrespective of production proximity (DMR 2011).

4.4.2 Contribution to economic development

On a macro-economic scale, mineral beneficiation activities can contribute to economic development through contributions to GDP and balance of payments as well as attracting foreign investments (DME 2007; Azapagic 2004). The iron and steel industry contributes to South Africa's balance of payments through exports across the value chain. In 2014, the steel manufacturing industry generated an export revenue of R 22.1 billion, from both primary and semi-finished products (SAISI 2015b). During the same period, R 12.4 billion worth of steel products were imported resulting in a net positive effect of R 9.7 billion (SAISI 2015d). The contribution of the foundry and scrap metal industry is estimated to be approximately R 10.6 billion per year (Conningarth Economists 2013).

4.4.3 Economic performance

The micro-economic performance of a multitude of companies leads to macro-economic benefits that spread to society via FDI, contribution to GDP, tax, royalties and payments to the public sector (Azapagic 2004). However, company performance is affected by a number of factors including profitability, market risk and access to raw materials.

4.4.3.1 Value addition

The increase of product value through further processing into semi-manufactured and manufactured products is commonly associated with greater economic benefits and therefore economic empowerment in resource rich nations (AU 2009; SDSN Thematic Group 10 2013). Figure 4-6 shows the increase in the value of commodities containing steel along the value chain. However, it must be noted that mining equipment and white goods are low steel intensity products (less than 10%), with steel accounting for a very small portion of the total costs (Anglo American 2011).

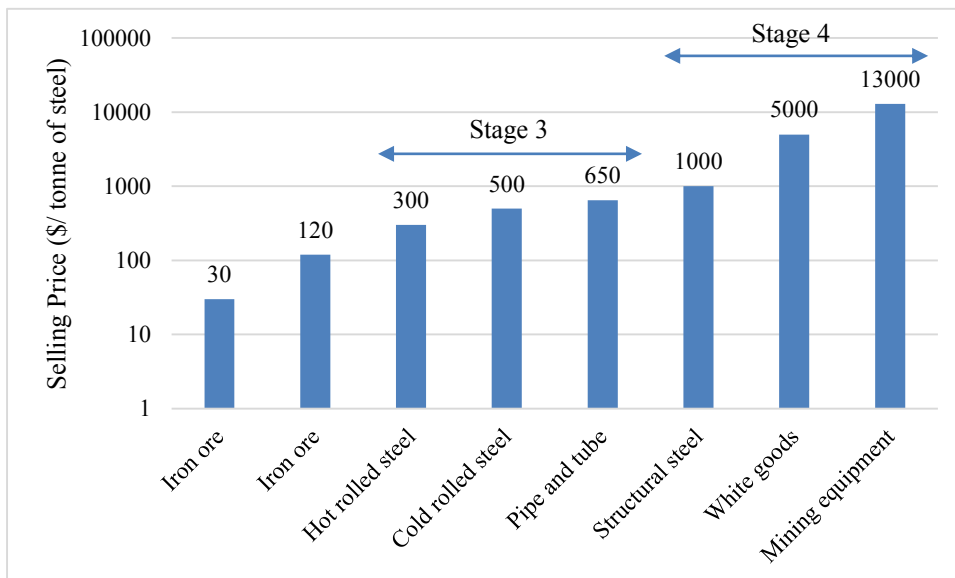


Figure 4-6: Selling prices of different commodities along the carbon steel value chain⁶ (DTI 2005)

4.4.3.2 Market risk

The lack of a secure market for goods serves as a deterrent for potential manufacturers. The domestic market is a key player in beneficiation; it not only supplies a secure outlet for sales but plays a vital role

⁶ The production of iron ore and iron are categorised under beneficiation stages one and two respectively.

in the "development of technological and market know-how" required to penetrate export markets (Robinson & von Below 1990; SDSN Thematic Group 10 2013). It is often necessary to supplement domestic sales with exports in order to realise economies of scales, however trade barriers limit access to global markets (DMR 2011). It is also necessary to take into consideration the comparative costs of importing processed products to ensure competitiveness of locally manufactured goods (Maposa 2013; SDSN Thematic Group 10 2013).

4.4.4 Energy

Energy security, consumption and costs are all major factors to consider when setting up a manufacturing process. Shortage or unreliability of critical infrastructure can have an impact on current and future beneficiation activities (DMR 2011; SDSN Thematic Group 10 2013). Of particular concern is the immense pressure that the South African power sector is currently under, which is threatening energy security. The challenge presented by a constrained energy system has led to loadshedding being implemented when there is insufficient supply to meet demand. In addition, rising energy prices reduce competitiveness of South African products in comparison with countries such as China, India and Malaysia (Maposa 2013).

In the wake of the current energy crisis, the high electricity intensity associated with the iron and steel industry essentially means it competes with demand from households. This may lead to energy supply to industries being prioritised over households, whereby households are more likely to be affected by loadshedding before industry.

From an environmental perspective, the majority of energy consumed in South Africa is fossil fuel based, which presents a major concern regarding associated CO₂ emissions. Primary iron production via the BF/BOF route makes use of coal as a primary energy source. The South African electricity mix is approximately 90% coal based, with the balance being a combination of nuclear and hydro power (DOE 2015). Therefore, processing routes that are reliant on electricity (e.g. electric furnaces), are associated with indirect CO₂ emissions resulting from the energy source.

4.4.5 Environmental performance

Globally, environmental performance is a key priority for the iron and steel industry (Fruehan 2009). In South Africa, a spotlight was placed on the environmental practices of major steel manufacturer ArcelorMittal South Africa (AMSA) regarding a legacy of pollution allegedly associated with their operations at Vanderbijlpark and Vereeniging steelworks in the Steel Valley. After many decades of the Steel Valley community alleging that AMSA operations were responsible for air, soil and groundwater pollution in the area, the Vaal Environmental Justice Alliance formally requested access to environmental records related to AMSA's operations in 2011 (AMSA v VEJA 2014). The records in question included an 'Environmental Master Plan' compiled in 2002, which AMSA cited as a confidential document that was no longer relevant in light of updated environmental legislation (AMSA 2014c). After their request was denied, VEJA successfully applied to the High Court to compel AMSA to release the records. After a failed appeal to the supreme court in 2014, AMSA released the environmental records to VEJA (AMSA v VEJA 2014).

4.4.5.1 Water management

Water management is a major environmental concern particularly in water stressed regions such as South Africa, where there is risk of manufacturing activities threatening water supply to surrounding communities. Therefore, minimisation of fresh water uptake and increased reuse and recycling of water is a key environmental priority (DME 2007). A key usage of water in the iron and steel industry is for evaporative cooling, in which water cannot be recovered for recycling (Fore & Mbohwa 2010).

4.4.5.2 Air pollution and climate change

Air pollution may have local, regional or global impacts, such as climate change. Primary steel production is a significant contributor to global warming through the production of CO₂ which is a major by-product when iron ore is reduced but not when steel scrap is recycled (Yellishetty et al. 2011). It is also associated with dust, NO_x, SO_x and volatile emissions which may impact negatively on health in the proximity of works. As such, atmospheric emissions reduction has been identified as a priority within the sector (Fruehan 2009; WSA 2013). In the foundry industry, dust emissions which are generated at every step of the process, are a major concern.

4.4.5.3 Waste production

The generation and disposal of solid waste and liquid effluents not only poses health and safety risks but also has financial implications related to legislation, treatment and/or disposal. Most South African foundries use sand in the production of moulds and cores, which is classified as hazardous waste (Meyer-Douglas 2013). As such foundries are required to obtain a waste management license for its storage and handling. Spent sand may only be delisted as general waste after testing. The iron and steel industry is also associated with slag production, the disposal of which can lead to negative environmental impacts (WSA 2013). Certain types of slags, on the other hand, are useful ingredients in cement manufacturing (Madlool et al. 2011).

4.4.6 Socio-economic performance

4.4.6.1 Contribution to employment

Governments are often under pressure to create employment opportunities in the minerals industry and often via downstream mineral beneficiation activities. However, it is necessary to take into consideration that although downstream mineral beneficiation is characterised with high capital intensity it may create relatively fewer jobs in comparison with the extractive industries (Baxter 2005). A study completed by the DTI (2005) compared the labour intensity across the various stages of iron and steel beneficiation. Their findings, illustrated in Figure 4-7, showed an increase in labour intensity, with value adding activities. Although the first two stages have been characterised by some as highly labour intensive (see Robinson & von Below 1990; Baxter 2005), this trend was not evident in the results of the study. This may be attributed to the choice of functional unit, in this case 1000 tonne of steel, which over-represents the numbers of jobs in cases where steel is not the only production input. Of particular interest is the distribution in labour intensities within the beneficiation stages. For example, the intensities for products manufactured in stage 3 ranged from 1.1 – 7 jobs per tonne of steel, but jump to 75-150 in stage 4 – even if divided by two to allocate some of these jobs to other input material value chains, the order of magnitude increase is clear. This shows that the potential for job creation is dependent on the level of beneficiation and puts into question whether a beneficiation strategy should focus on all four stages, or bypass stages 2 and 3 and rather focus on stage 4.

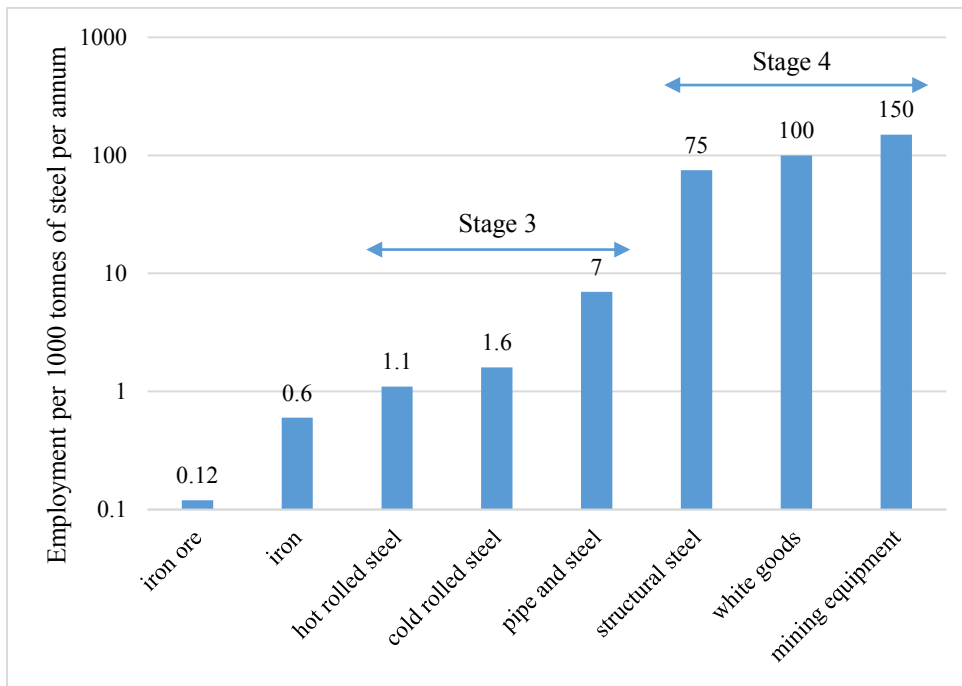


Figure 4-7: Labour intensity of different mineral beneficiation activities along the carbon steel value chain (DTI 2005)

4.4.6.2 Skills Availability

Although mineral beneficiation has the potential to create significant employment opportunities mainly in goods manufacturing, the lack of skills, particularly in the engineering and technical fields, necessitates a dependence on imported skills (DMR 2011; Maposa 2013; SDSN Thematic Group 10 2013). However, investment in value-adding activities may stimulate investment into skills development decreasing expatriate hires in the long term. The specific skills profile in demand is dependent on a number of factors including the products being manufactured and the specific processes and technologies being employed.

4.5 Sustainability Indicator Framework Development

In order to conduct a sustainability performance assessment of the three alternatives under consideration, a sustainability indicator framework was developed based on the sustainability issues identified. However, it was necessary for a comparative basis to be established before the indicators could be defined.

4.5.1 Comparative basis

The establishment of a comparative basis for the sustainability performance assessment was dependent on the system boundaries of the alternatives under consideration. These system boundaries, illustrated in Figure 4-8, were defined in line with the decision question; the fate of recycled scrap steel. As the question pertains to the fate of scrap after processing by metal recyclers the system boundaries do not include the impacts associated with scrap metal processing. Furthermore, the environmental, social and economic impacts associated with this activity would be common to all three alternatives.

A gate-to-gate approach was utilised whereby the alternatives were evaluated according to the processing routes the recycled scrap metal undergoes when it enters the factory gates. For scrap

exporting, the system has been defined as the port, through which the scrap metal passes through prior to exporting. In the case of the steel mills, as the majority of steel manufacturers produce semi-finished products, these have been considered as the final product from this process. The steel mill system includes scrap processed via the three major steel production route: BF/BOF, DRI/EAF and EAF. Foundries process scrap metal into a variety of castings which were considered as the final product.

Detailed process flowsheets of the alternatives are available in Appendix G.

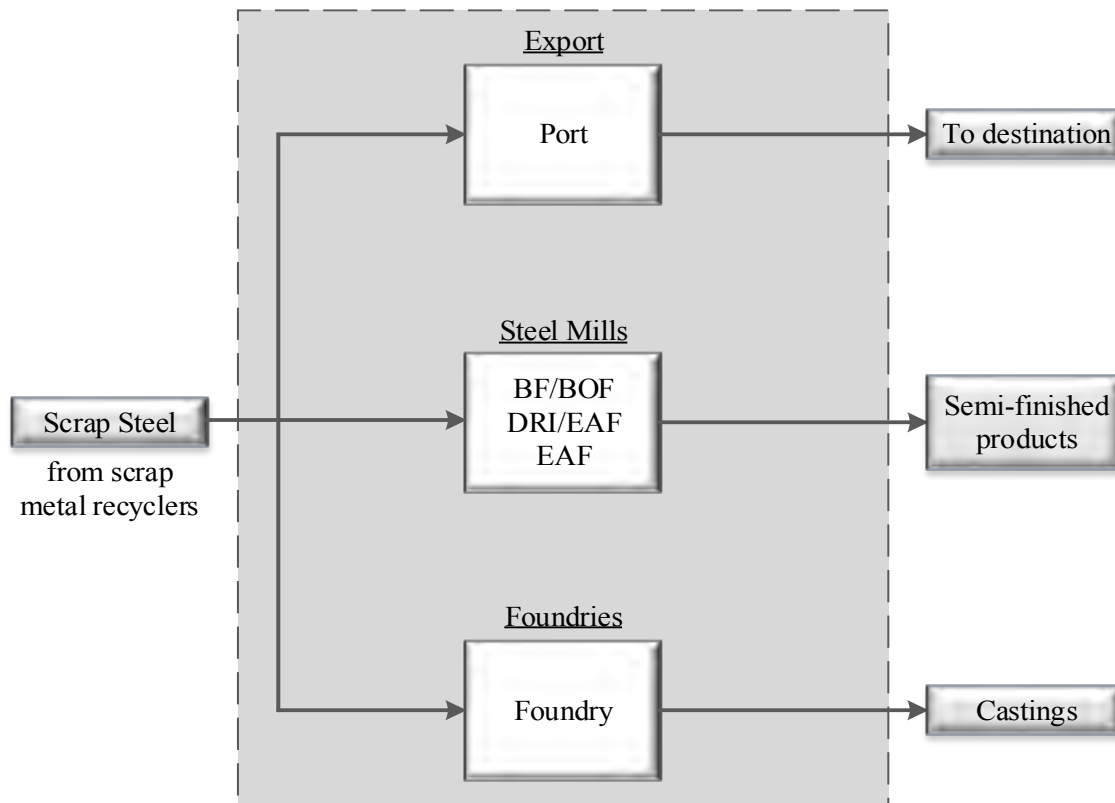


Figure 4-8: System boundaries of alternatives under consideration

Based on the system boundaries a comparative basis can be established. Although the study is focused on the options for the fate of recycled scrap, the choice of scrap metal as a comparative basis may lead to misrepresentation of the sustainability impacts associated with an alternative. This is of particular concern in cases where the final product does not utilise scrap as the only production input, as in the case of primary steel production which utilises iron ore as the primary raw material. As shown in section 4.4.6.1, the choice of steel as a basis led to an over-representation of the job intensity in cases where steel was not the only production input. Therefore the alternatives were compared on an industry basis, which took into consideration the current total production levels of the range of products being produced. Furthermore, the study is focused on the potential sustainability benefits presented by increasing consumption in a particular industry and not on the production of a specific product.

4.5.2 Sustainability indicator framework

A sustainability indicator framework was developed by translating the issues identified in section 4.4 into quantitative and qualitative performance measures. It was necessary for the issue of air pollution to be disaggregated into lower level criteria representing the types of emissions relevant to the iron and steel industry.

As discussed in section 4.5.1, the alternatives were evaluated on an industry basis whilst taking into consideration production levels where appropriate. The final choice of units also took into consideration convention from relevant indicator frameworks reviewed in literature as well as sustainability reports⁷. In the case of macro-economic issues, these are evaluated according to the overall contribution of the industry. In the iron and steel industry, environmental indicators are commonly reported in reference to molten metal (Fatta et al. 2004; Yellishetty et al. 2011; AMSA 2014c). Therefore the same convention is followed in this study.

Table 4-4: Sustainability indicator framework

Issue	Indicator	Unit
Capacity	Amount of product	kilotonnes
Access to raw materials	Total amount of ferrous scrap metal generated in South Africa	kilotonnes
	Amount of scrap consumed	kilotonnes
Contribution to GDP	Direct contribution to GDP	R (billion)
Contribution to balance of payments	Contribution to balance of payments	R (billion)
Production costs	Production costs	R/t product
Value addition	Sales value of commodity	R/t product
Profitability	Gross profit margin	%
Market risk	Proportion of product currently imported	%
Energy	electricity consumption	GJ/t molten metal
Water management	Water consumption	m ³ /t molten metal
Air pollution and climate change	Direct CO ₂ emissions	tonnes CO ₂ /t molten metal
	NO _x emissions	kg/t molten metal
	SO _x emissions	kg/t molten metal
	Particulate Matter	kg/t molten metal
Waste production	Total weight of effluents and waste produced	kg
Job creation	Number of direct employees	employment/ kilotonnes of product
Skills availability	Proportion of jobs requiring skilled labour	description

4.6 Summary

The scrap metal industry poses a number of options for the fate of recycled metal; they can be exported or beneficiated locally in steel mills or foundries. As discussed in section 4.2.2, the export of scrap has been identified as a significant concern to some in the iron and steel industry as it is viewed to come at

⁷ A review of indicator frameworks which informed this study is available in Appendix A.

the expense of local beneficiation in steel mills and foundries. In particular, increasing exports are viewed as hampering access to affordable and quality scrap metal for local processors. However, the iron and steel scrap industry faces a number of sustainability issues (discussed in section 4.4) beyond the issue of scrap metal availability. These issues span all dimensions of sustainable development, including economic, environmental and socio-economic factors. Thus decision-makers are faced with the decision of which option for scrap metal processing has the most potential benefits.

The results presented in this chapter inform the problem analysis stage of the decision-making process, which is presented in Chapter 5 and Chapter 6. Chapter 5 explores stakeholder perspectives on the decision situation (section 4.3) as well as the relative influence of different sustainability issues on decision-making. In Chapter 6, the alternatives are evaluated according to the sustainability indicator framework developed in section 4.5.2.

Chapter 5 Iron and Steel Scrap Industry Stakeholder Value Systems

As discussed in section 2.3.2, engaging stakeholders and understanding their concerns is an integral part of decision-making. The objectives and preferences of stakeholders will inherently influence the final choice of decision alternatives. Therefore it is important to gain an understanding of stakeholder value systems which underpin their perspectives on the fate of recycled scrap metal. Therefore, a series of interviews was conducted with stakeholders in the scrap steel industry, according to the protocol presented in section 3.6. The purpose of these consultations was to ascertain stakeholder perspectives on the decision situation (discussed in section 4.3), including gaining an understanding of the impacts of the sustainability issues presented in section 4.4. The interviews also included a preference elicitation exercise (discussed in section 3.6) which enabled the researcher to gain an insight into stakeholder value systems during decision-making.

This chapter presents the results of the interviews with stakeholders and analyses of the relative influence of different factors on stakeholder decision-making in this context. Section 5.2 presents a discussion of stakeholder perspectives on the decision situation, which includes their perspectives on the level of interaction amongst stakeholders in the industry. This is followed by a discussion of the results of preference elicitation exercise (section 5.3). More specifically, the importance placed on sustainability issues by different stakeholders (section 5.3.2), as well as their relative importance on individual stakeholder decision-making processes (section 5.3.3) are discussed.

5.1 Interviewees

A total of ten stakeholders in the scrap steel industry were consulted as follows:

Table 5-1: Participant details

Participant ID	Role	Nature of interaction	Location
Participant 1	Metal recycling	Face - to - face	KwaZulu-Natal
Participant 2	Metal recycling	Face - to - face	Western Cape
Participant 3	Metal recycling organisation	Face - to - face	Gauteng
Participant 4	Metal recycling/ Foundry	Face - to - face	Gauteng
Participant 5	Foundry	Face - to - face	KwaZulu-Natal
Participant 6	Foundry Organisation	Face - to - face	Gauteng
Participant 7	Metal recycling/ Steel Mill	Face - to - face	Western Cape
Participant 8	Steel Mill	Face - to - face	KwaZulu-Natal
Participant 9	Institutional - finance	Electronic	Gauteng
Participant 10	Institutional - trade and industry	Electronic & Telephonic	Gauteng

The majority of participants were high-ranking members of their respective firms, who were actively involved in decision-making. As such the participants were well versed with the current debate surrounding scrap metal and the alternatives under consideration. In order to increase the diversity of the sample, the firms under consideration had different profiles, particularly in relation to their size and operation. Participants in the metal recycling industry ranged from smaller firms which engage in preliminary sorting and partial processing of scrap, to larger operations which process the scrap further into primary steel products such as billets. The same applied to the steel mills and foundries whereby

there were differences in the size and operations of the firms. Participants also included members of associations representing industry players, i.e. participants 3 and 6. Institutional participants were affiliated with national government departments. In addition, the sample was geographically diverse comprising of participants from two coastal provinces (KwaZulu-Natal and Western Cape) and one inland province (Gauteng). This enabled the exploration of the potential influence of firm location on the fate of recycled scrap metal and stakeholder perspectives on the decision situation. Although participants representing institutions (9 and 10) and industry organisations (3 and 6) were located in Gauteng their interests were nationwide.

As discussed in section 3.6, the stakeholder consultation process took the form of semi-structured interviews. The majority of interviews were conducted face-to-face which allowed for questioning of rationale behind responses. In cases where this was not possible a combination of electronic and telephonic correspondence was utilised. Maintaining the anonymity of the participants was an important element of the study (discussed in section 3.7). Therefore, as some of the information contained in the transcripts may reveal the identities of the participants, summaries of the interviews are available in Appendix E.

5.2 Stakeholder Perspectives on the Decision Situation

The interviews provided many insights into stakeholder perspectives regarding the decision situation regarding the fate of recycled steel, as well as stakeholder interactions within the industry at large.

5.2.1 Local beneficiation vs export

When it came to the matter of increasing local beneficiation of steel scrap, none of the participants were opposed to the idea in principle. They were in support of increased economic growth and the role their firms could play in its promotion. The participants were also very attune to the sustainability issues being faced by their counterparts in the scrap metal industry, and were willing to support initiatives to support the survival and flourishing of all sectors. However, understandably, none of the participants were willing to support initiatives (e.g. strategies or policies) that they felt would put their own firms at risk. As such, some participants came across as very defensive in the consultation which was coupled with a general sense of distrust and tension within the scrap steel industry. This was particularly evident in relation to the current drive to remediate the decline of the foundry industry.

Although most participants (1-4) in the recycling industry were in support of increased local scrap consumption, many (participants 1-3 and 7) felt that they were being unjustly implicated as the primary cause for the decline of the foundry industry⁸. Participants expressed their support for local consumption of scrap metal, emphasising, however, that exported scrap consisted mainly of grades that are unsuitable for processing domestically. The geographical setup of the South African manufacturing industry, whereby major consumers are located inland, was also cited as an important factor in determining the fate of scrap metal. In general, scrap generated inland was consumed locally whereby coastal recyclers were more likely to export scrap. This is due to the logistical costs associated with transportation of scrap inland, which would greatly increase the costs of scrap making this option inviable financially. Participants 1-3 also refuted claims that current scrap prices were exorbitant as they were based on

⁸ In reference to allegations that scrap exports have led to a shortage of scrap on the domestic market, hampering access to affordable and quality scrap for consumption in local foundries.

international market prices which the local consumers they dealt with were willing to pay. In reference to the variety of issues that the foundry industry is facing, metal recyclers 1-3 and 7 felt that the spotlight had been placed on them as they were “an easy target” (participant 3) being sacrificed for the benefit of another industry.

“We would love to supply locally, if they would take all our stuff.” – Participant 2

Participants (4-6) in the foundry industry are reportedly facing a multitude of sustainability issues related to competitiveness including rapidly increasing energy costs, labour productivity, skills availability, technology adaptation and particularly access to and competitiveness in the global market. Whilst access to raw material was cited as a sustainability issue, this was in relation to the availability of quality scrap that is suitable for consumption within the foundry industry. Foundries require a steady supply of high quality scrap that is clean and free of deleterious material that could influence the efficiency of the process. There are currently suspicions within the industry that this scrap is preferably being exported forcing foundries to utilise material which is not suited to their operations. This not only results in lowered efficiency but may also lead to increased negative environmental consequences. However, none of the participants voiced the opinion that the decline of the industry can be directly attributed to decreased availability of affordable and quality scrap. Additionally, none of the participants were against the exporting of scrap in principle. Instead they advocated for a multifaceted approach to improve the competitiveness of the foundry industry.

“I am not saying that availability, price or quality of scrap material dictates whether in fact a particular foundry is more or less competitive against the Chinese or Europeans. It’s a multi-factorial thing.” – Participant 6

Participants (7 and 8) in the steel mills were dependent on scrap metal to varying extents. Participant 7 produced secondary steel from scrap whereas participant 8 primarily relied on iron ore as a raw material. Despite this difference, both participants were in favour of scrap exportation. Whilst they supported the promotion of local beneficiation, they also believed that supply and demand forces need to be taken into consideration. Both participants cited competitiveness as a key challenge in the industry, with consumers struggling to compete against cheap imports from countries such as China.

“It is better for us to take scrap and export it than to try and convert it locally into a product.” – Participant 7

Institutionally, exportation of scrap metal is seen as a direct threat to the survival of the scrap metal industry. However, the two participants (9 and 10) differed on some key issues. The perspectives of participant 9 regarding sustainability issues currently being faced by the industries were more aligned with those articulated by participants in those industries. The participant emphasised the need for increased availability of scrap that meets the quality requirements of processors, however they were also aware of the other issues that the industry is currently facing such as energy and increasing production costs. In contrast, participant 10 attributed the decline of the scrap consuming industry to increasing scrap exports. The participant viewed scrap as integral to industrial development, and the increased availability of cheap scrap within the country as a way to attract investors in the manufacturing industry.

“The interest of government is to ensure adequate competitive supply into the local industry for value addition which may not be in the interest of the [scrap] dealers.” – Participant 10

5.2.2 Industry perspectives on the policy directive regarding scrap exporting

The policy directive regarding scrap exporting (reviewed in section 4.2.2) has been met with mixed reviews within the scrap metal industry. However, the general sentiment was that thus far the policy had been unsuccessful in achieving its intended objectives.

Many metal recyclers (1-3 and 7) felt that the policy directive on the exportation of scrap metal was designed to promote benefit to the consuming industries to the detriment of the recycling industry. Of particular concern were the potential consequences the preferential pricing system could have on informal scrap collectors as well as generators of new scrap. Participants 1 and 7 pointed out that a depression in the scrap prices would force recyclers to drop their buying price of unprocessed scrap so as to maintain profit margins. This would have dire consequences for informal collectors who are dependent on scrap collection as a source of income. This price drop would also affect downstream manufacturing industries, which pay full price for metal inputs, and would now be forced to sell generated new scrap at a fraction of the original value. This results in loss of revenue in a sector that the government is trying to grow. Within the recycling industry there were mixed responses regarding the effect of the policy on current operations. In the case of participant 3, historical agreements with consumers were in place which supersede the preferential pricing system. Furthermore, the participant was yet to receive any applications from local consumers for the purchase of scrap advertised for export. In contrast, participants 2 and 7 reported incidents whereby consumers had expressed an interest in purchasing scrap advertised for export but had neglected to follow through. According to the same participants, the policy had also introduced a lot of uncertainty into the recycling industry. This was in particular reference to the waiting periods imposed by the policy for the processing of permit applications. Previously, scrap purchase agreements were concluded prior to scrap processing but this was no longer possible as the export permit application requires scrap to be ready for inspection at the time of application. This has increased the risk associated with buying large sources of scrap, e.g. a decommissioned mine or aircraft, as the recycler is forced to do so without the guarantee of a buyer. Furthermore, the increased time period left recyclers more vulnerable to fluctuations in the exchange rate and market prices potentially affecting the final value of scrap metal and consequently profit margins. However, not all participants in the metal recycling industry were against the introduction of the policy intervention. Participant 4 was in support of the policy, and viewed it as an opportunity to expand into the consuming industries via the purchase of a foundry. Whilst the other participants were very vocal in their objections to government intervention participant 4 chose a different approach in support of the government. Yet, all participants were currently facing similar sustainability issues.

“Why fight the government? You’re not going to win!” – Participant 4

Metal recyclers 1-3 and 7 did not agree that scrap availability was a legitimate issue with regards to the current decline of the foundry industry. Participant 3 described government as being very reactive to a “plight from a dying industry.” They did not view the decline as a local phenomenon, whereby globally inefficient foundries were being overtaken by larger and more competitive foundries. However, all metal recyclers agreed that the foundry industry needs help and were willing to participate in the process of how that would be achieved. This was evidenced by an earlier initiative between the recycling and

foundry industries, whereby they had engaged extensively in an attempt to formulate amicable solutions that would remediate the decline of the foundry industry⁹. The results of this consultation process, which included a scenario analysis of various options, had been presented to government. However, participants 1 and 3, who were both involved in the consultation process, felt that this work had been disregarded as the policy directive was contrary to the findings of the report.

“It doesn’t seem there is a logical thought process behind government decisions.” – Participant 7

All participants in the foundry industry regarded the policy intervention as having little to no effect in the foundry industry. In the perspective of participant 6, the policy had failed for two reasons. Firstly, the majority of scrap grades listed on export applications were not suitable for processing in the foundry industry. In cases where suitable material was listed, the foundries and applicants had been unable to dialogue regarding sale of the material. Participant 5 expressed the suspicion that high grade scrap was being added as a “sweetener” to consignments destined for export, and was not reported on permit application effectively making it less available to local consumers. Although participant 4 viewed the introduction of the policy as “an opportunity to make some money”, they have been unable to maximise on the opportunity due to the myriad of challenges the foundry industry is currently facing. Participant 5 believed that government needs to be more innovative in their policy development, which could only be achieved through active engagement with industry. This would enable the government to develop an understanding of the challenges that need to be overcome in order to achieve their objectives.

“In order to be innovative, you’ve got to make sure that the guys on the ground have had their input.” – Participant 5

As mentioned in section 5.2.1, steel mill participants were in favour of scrap exportation as it was an internationally tradeable commodity. Both participants were openly against the policy intervention, with participant 7 describing it as anti-competitive and against international trade agreements. Furthermore, the participants did not believe the intervention would achieve government’s ultimate goal of promoting downstream industries. This was due to the fact that local steel mills that currently provide inputs into downstream manufacturing industry rely on iron ore as a raw material, therefore increasing scrap consumption would have no effect on production of inputs for downstream industries. Instead, scrap was consumed primarily for the manufacture of construction products.

“The scrap available should be at market related prices and the scrap recycler should be at liberty to export.” – Participant 8

5.2.3 Stakeholder engagement within the iron and steel scrap industry

Overall, there were mixed responses regarding the level of stakeholder engagement within the scrap metal industry. There was a general sense of disgruntlement amongst the majority of industry players (participants 1-3 and 5-7) regarding the current level of stakeholder engagement within the scrap metal industry, particularly between industry players and institutional entities. In the case of participants 1

⁹ The results of this process contributed to the “*Employment promotion programme phase III (EPP) - foundry and scrap metal industry economic impact study*”(Conningarth Economists 2013).

and 3, who had reportedly tried to engage with government on numerous occasions (as discussed in section 5.2.2), they felt as though their concerns had not been taken into consideration during the decision-making process. From the perspective of participant 5, government was not seen to be proactively engaging with industry. Instead, they viewed government as developing policies without fully understanding the challenges that need to be overcome in order to achieve their objectives. Participants 4, 6 and 8 reported high levels of engagement with government institutions. However, similarly to participants 1 and 3, participant 6 did not necessarily feel that their opinions were taken into consideration when decisions were being made. All industry participants agreed that there was a need for increased interactions between industry and institutions in order to promote greater understanding of the different sustainability issues being faced by different stakeholders, and ultimately the formulation of strategies that ensure sustainable growth of the industry. Nonetheless, all of the participants engaged willingly with the interview process and were eager to provide information that would enable people to gain a better understanding of the industry and their perspectives.

“I think we all have the same objectives, how we reach them is the grey area. We need to sit down and dialogue... Government is going to be crucial in whether they are prepared to sit down and have a platform where these issues are going to be discussed” – Participant 3

“There is a spirit of corporation and a drive to reach consensus in the steel industry.” – Participant 8

5.3 Stakeholder Preference Elicitation

In order to gain an insight into stakeholder value systems in decision-making, each of the participants completed a preference elicitation exercise (available in Appendix C). The exercise required them to rank and score the sustainability issues identified in Section 4.4, providing an insight into the relative importance placed on different issues when faced with the decision of increased local consumption vs export of scrap. The results of this exercise are presented in three different sections. The ranking and scoring of sustainability issues are presented in sections 5.3.1 and 5.3.2., culminating with an analysis of stakeholder value systems based on the relative influence of issues on their decision-making process in section 5.3.3.

As participant 4 had recently entered the foundry industry, they were requested to complete the exercise from two perspectives; as an established member of the recycling industry and as a recent entrant into the foundry industry. The results of these two perspectives are referred to as “4a” and “4b” respectively. This comparison also provided insight into the extent to which personal principles relative to vested interests may influence stakeholder decision-making.

Detailed results of the preference elicitation exercise are available in Appendix F.

5.3.1 Ranking of sustainability issues

The ranking of sustainability issues provided an insight into which issues the stakeholders considered to be relevant in their individual decision-making processes. An overview of the ranking exercise is presented in Table 5-2, which shows the highest and lowest ranks achieved by an issue as well as how frequently the issue appeared in the top 5 and how often it was considered irrelevant. In terms of the most highly ranked issues across the board, the following issues were most frequently ranked in the top 5:

- Production costs
- Profitability
- Access to raw materials
- Market risk
- Energy

Production costs and market risk were least likely to be considered irrelevant by stakeholders although the importance placed on them varied. Whereas production costs were consistently ranked relatively highly amongst stakeholders, the importance placed on market risk varied. Macro-economic issues (contribution to GDP and balance of payments) were more likely to be considered irrelevant across the industry, in comparison to other issues, irrespective of stakeholder role. Instead, more emphasis was placed on micro-economic issues directly related to the financial performance of the firm. Energy was viewed as an important threat to sustainability particularly in the consuming industries which are characteristically highly energy-intensive. Although the importance of environmental issues was acknowledged they were never ranked higher than 5th in order of importance.

Table 5-2: Ranking of sustainability issues

Sustainability issue	Ranks		Frequency	
	Highest	Lowest	Irrelevant	Top 5
Access to raw materials	1	9	2	7
Contribution to GDP	6	13	5	1
Contribution to balance of payments	5	13	5	1
Production costs	2	6	1	9
Value addition	5	10	3	2
Profitability	1	10	2	8
Market risk	1	11	1	6
Energy	2	8	2	6
Water management	5	12	5	2
Air pollution	5	13	3	1
Waste production	5	11	3	1
Job creation	3	8	2	5
Skills availability	1	9	3	5

5.3.2 Scoring of sustainability issues

The results of the scoring exercise are presented according to sustainability issues, enabling comparison of different stakeholder perspectives on the sustainability issues in this decision-making context. Of particular interest are the scores assigned by members of the same industries. The following key is used to distinguish the roles of the stakeholders:

Metal Recycling				Foundries			Metal Recycling/ Steel Mill			Steel Mill		Institutional	
1	2	3	4a	4b	5	6	7			8		9	10

As a relative scoring method was employed the scores can only be taken as an indication of which issues the stakeholders consider to be relevant as well as the importance placed on them. The relative influence of the different issues in decision-making will be explored in the proceeding section.

5.3.2.1 Access to raw materials

Scrap recyclers essentially compete with one another to acquire good quality scrap metal for processing and the availability of scrap is dependent on the region under consideration. However, raw material availability was not considered to be an issue for two of the four recyclers (illustrated in Figure 5-1) implying they had access to a steady supply of good quality scrap metal.

As discussed in section 5.2.1, none of the consumers were against scrap exporting in principle, recognising its value as an internationally tradeable commodity. Instead, their concerns surrounded increased availability of scrap that meets their specifications. However, participants 6 and 8 assigned it a relatively low importance in comparison to other consumers (shown in Figure 5-1). In the case of participant 8, scrap does not form a major input into their operations. Whilst participant 8 acknowledged the relevance of access to raw materials, it was assigned a relatively low importance as it does not form a major input into their operations. When viewed in the context of the other sustainability issues the foundry industry is currently facing, participant 6 assigned access to raw materials a relatively low importance.

Institutionally, scrap exporting was viewed as the biggest threat to the survival of the scrap consuming industry. However, there was a slight deviation in their perspectives regarding quantity vs quality; participant 9 placed more emphasis on the availability of quality scrap whereby participant 10 held the view that the exportation of scrap has led to a general shortage of scrap metal in South Africa. Throughout the consultation process participant 10 was very emphatic regarding the issue of scrap availability, with availability of scrap on the local market being viewed as integral to increased industrialisation and consequentially job creation and economic growth.

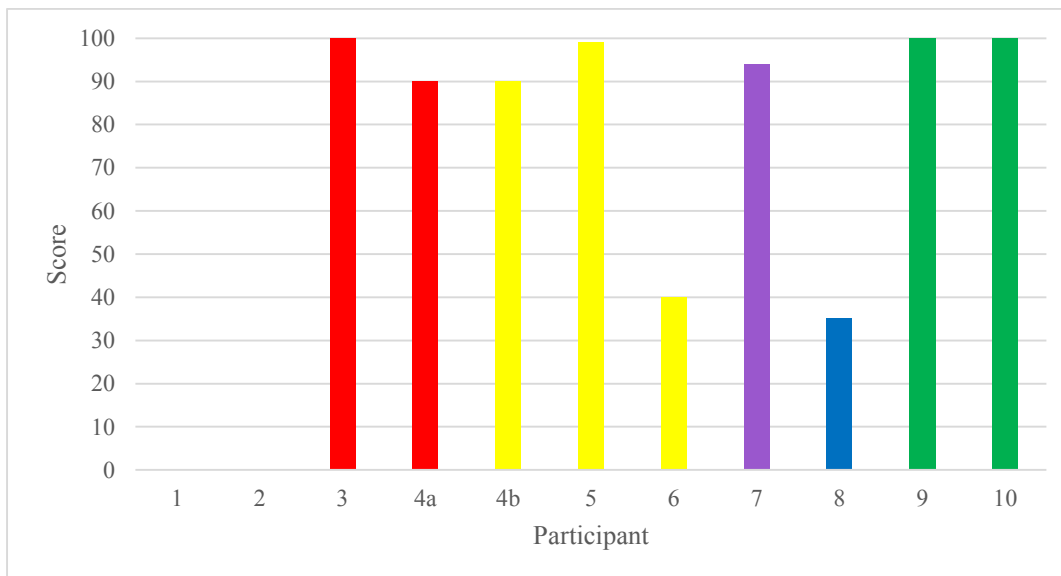


Figure 5-1: Scoring of the sustainability issue "access to raw materials"

5.3.2.2 Contribution to GDP

As the focus of institutions is on national economic growth, macro-economic issues such as contribution to GDP were considered relevant by both institutional stakeholders, but scored very differently. Overall, the importance placed on contribution to GDP varied across the industry, irrespective of stakeholder role. This variation pointed to the influence of stakeholders' personal principles and belief when making

decisions. Their personal value system determined whether or not they chose to take a micro- or macro perspective when making decisions. In other words, whether they chose to make decisions based solely on potential impacts on their firms or if knock-on effects beyond the firm were taken into consideration. To illustrate, participants 1, 4 and 6, who each considered contribution to GDP a relevant factor, spoke of their desire to see increased national economic growth, and to actively contribute to that growth.

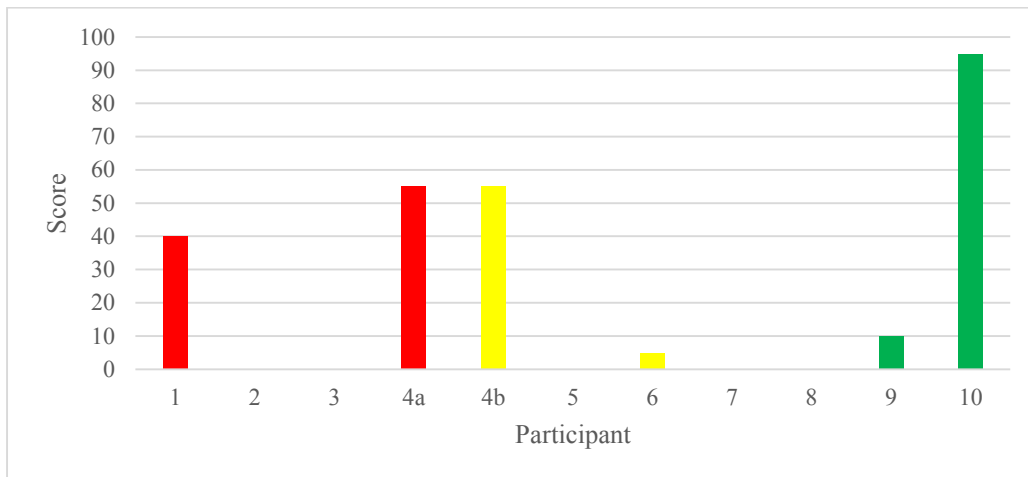


Figure 5-2: Scoring of the sustainability issue "contribution to GDP"

5.3.2.3 Contribution to balance of payments

In terms of relevance, contribution to balance of payments was ranked similarly to contribution to GDP. The same reasoning was employed by stakeholders, where participant 10 was driven by the macro-economic performance of the nation, and the perspectives of industry stakeholders was influenced by their personal views beyond the operation of their firms. As such, the same participants who considered contribution to GDP relevant also considered contribution to balance of payments as relevant to their decision-making process. The influence of personal beliefs is also evidenced by the fact that participant 4 assigned similar scores to the respective issues from both a foundry and metal recycler perspective.

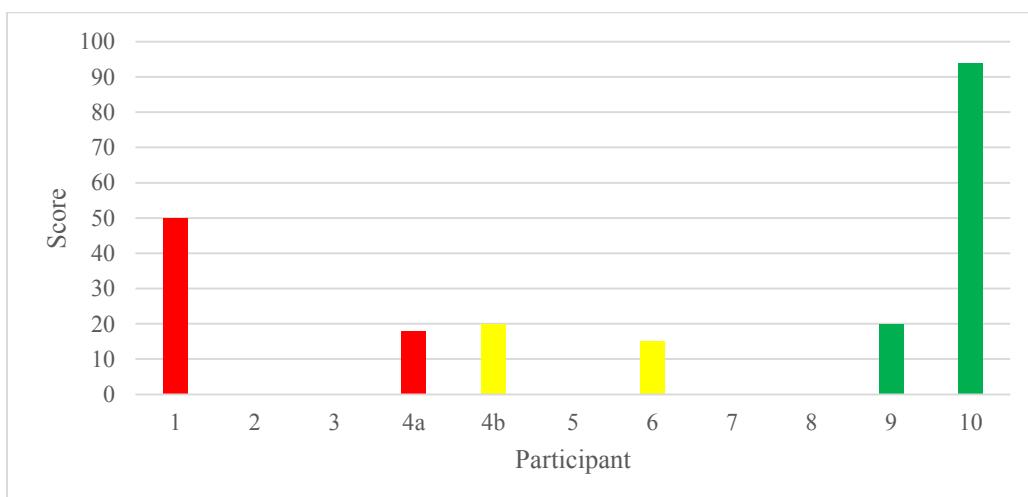


Figure 5-3: Scoring of the sustainability issues "contribution to balance of payments"

5.3.2.4 Production costs

In the metal recycling industry, production costs are dependent on the processing methods employed. In cases where scrap recyclers would need to employ additional processing to meet local consuming industry specifications, production costs would become a relevant factor in the decision to supply scrap domestically. Therefore, the relevance of this particular issue is dependent on the level of processing employed by metal recyclers and whether or not the recycler will be able to maintain desired profit margins. In the cases of participants 3 and 4, their regular processing of scrap to consuming industry standards reduced the relevance of this particular issue to the decision of whether to increase local consumption of scrap.

Production costs were of particular concern to consuming industries and institutional stakeholders, as it was directly linked to their competitiveness on the global market. More specifically, industry stakeholders were facing challenges pertaining to increasing input costs, rising electricity costs, labour productivity and rising overheads. However, competitiveness was widely viewed as a multi-factorial issue whereby production costs are a contributing factor. Production costs were also scored highly by institutional stakeholders, as it was directly linked to increased profitability and overall increased competitiveness on the global market.

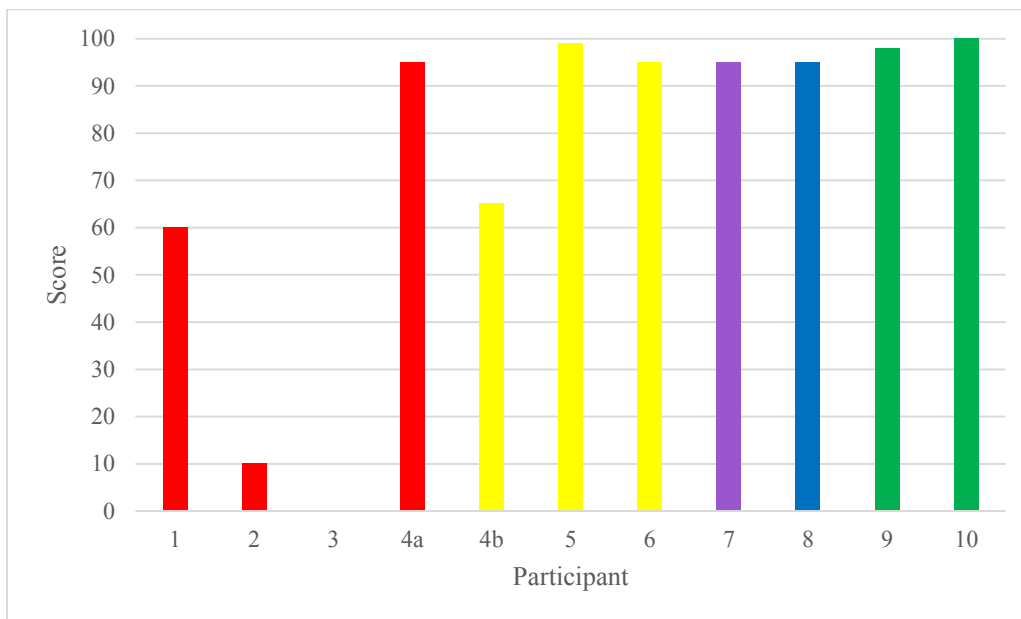


Figure 5-4: Scoring of the sustainability issue "production costs"

5.3.2.5 Value addition

Value addition was generally scored more highly by participants in the consuming industries than those in metal recycling. This may be attributed to the fact that consuming industries engage in the production of high value products which is associated with greater economic benefits. Therefore, the amount of value added is directly related to a firm's economic performance. On a macro scale, increased value addition via minerals beneficiation is a national priority due to the potential contributions it can make to the national economic output making it a priority for institutions.

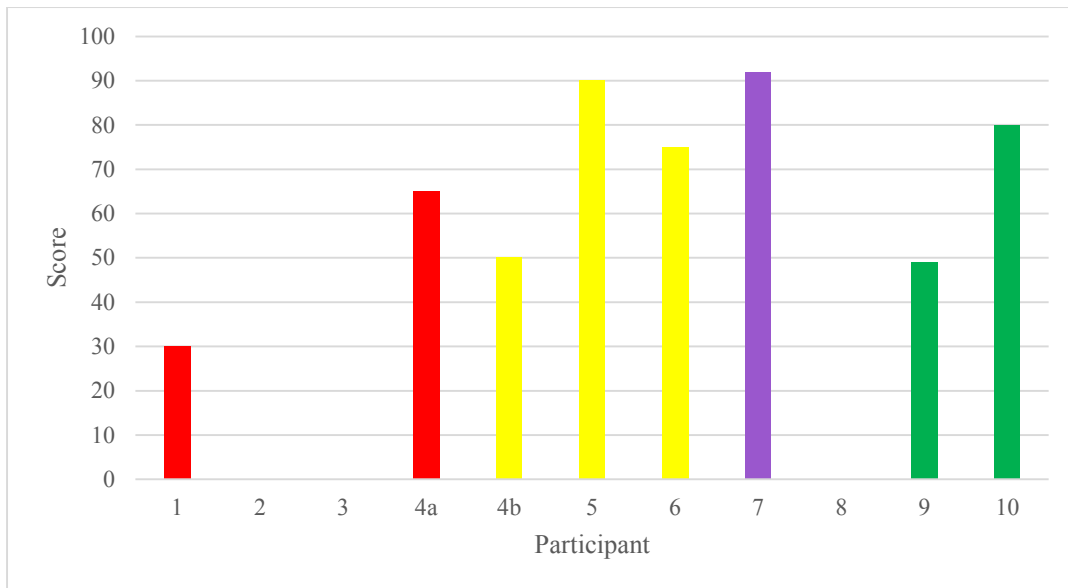


Figure 5-5: Scoring of the sustainability issue "value addition"

5.3.2.6 Profitability

The importance of profitability in the steel scrap metal industry was summed up convincingly by participant 3:

"We all have a common goal – we want to maximise profits!"

Profitability is a key driving factor in all private industries, as it is directly linked to the economic viability of a firm. In the case of metal recyclers, the pricing structure employed by the firm plays a role in how relevant it is deemed in relation to the current decision situation. Participants 2 and 3 did not deem it to be a relevant factor as their pricing structure ensured that they maintained the same profit margin regardless of the product market. The current decline in the consuming industries makes profitability a highly important factor as it points to the survival of the firm. Therefore, any decision to increase local beneficiation locally will be greatly influenced by the potential profitability of the venture.

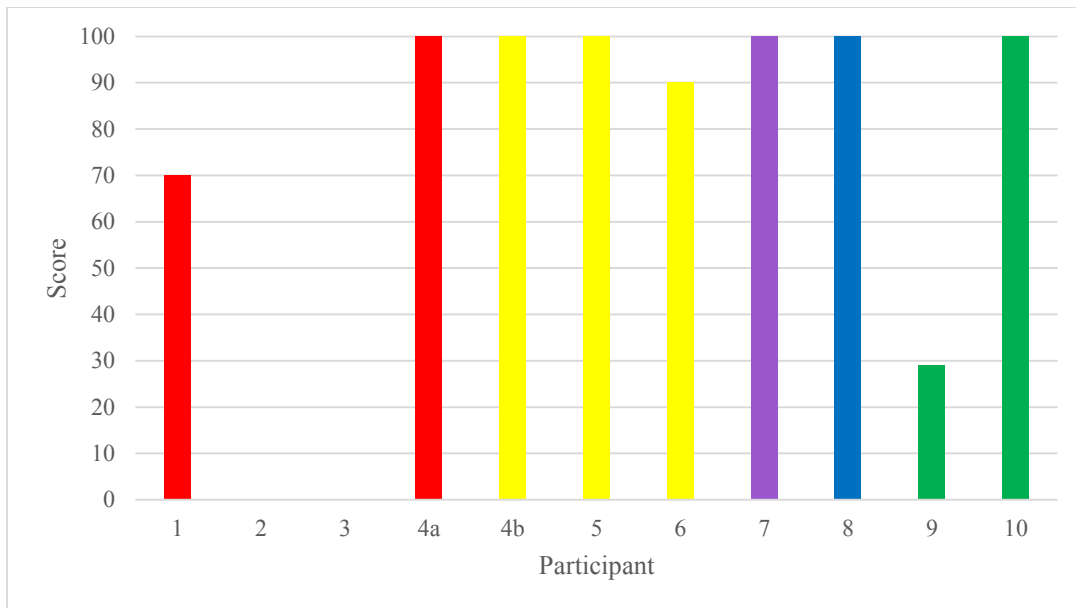


Figure 5-6: Scoring of the sustainability issue "profitability"

5.3.2.7 Market risk

The importance of a secure market for goods was evidenced by the fact that it was a relevant factor to the majority of stakeholders (1–9) across the board, albeit to varying extents. The lack of a domestic market for the lower grades of scrap, which cannot be consumed in local industries, was commonly cited as a mitigating factor for the exportation of scrap. The current capacity of local consuming industries was also a concern in that a ban on scrap exportation would result in an over-supply of scrap on the domestic market.

According to participants 6–8, influx of cheaper imports has threatened the ability of consuming industries to remain competitive, decreasing their domestic market share. Participant 7 compared the promotion of increased local production, without the assurance of a secure market, to “putting the cart before the horse.” With respect to the steel mills, worldwide excess capacity of steel has led to the domestic steel market being flooded by cheap imports against which local consumers cannot compete. As a result, producers are forced to reduce their capacity as there is decreased domestic demand. Producers are also unable to compete on the global market ruling out exporting as an option. Therefore, the availability of a secure market is essential before the decision to produce a commodity can be made.

Participant 10 was the only stakeholder who did not consider market risk to be relevant in their decision-making process. Although they acknowledged the decreased market share of local commodities both domestically and globally, the direct linkage between competitiveness and market access served as the basis for their decision. By increasing the competitiveness of local industries through lowered input and production costs and increased profitability, this would, in their view, lead to increased market share.

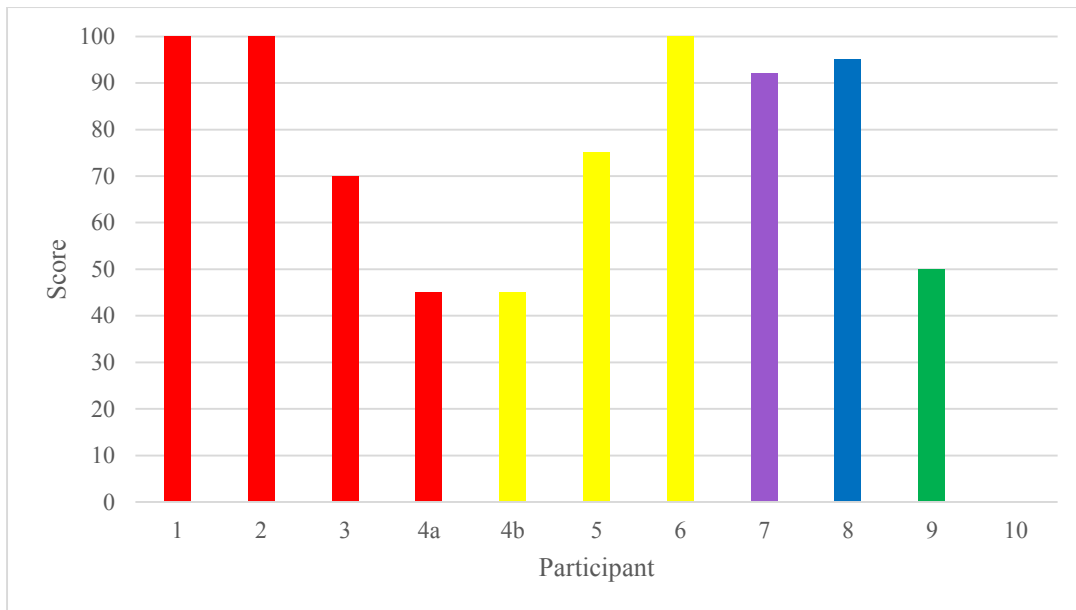


Figure 5-7: Scoring of the sustainability issue "market risk"

5.3.2.8 Energy

Energy is a major issue, particularly in the energy intensive consuming industries which are dependent on electricity as their primary source of energy for their operations. This can be attributed to the current threats to energy security presented by rising energy costs and load-shedding. The implementation of load-shedding not only negatively impacts the number of productive hours of a firm, it also leads to increased energy requirements due to more frequent start-ups and shut-downs of furnaces, as more energy is consumed in heating them for operation. In some cases, losses incurred during load-shedding are so severe that the survival of a firm is threatened.

“With the way things are, electricity is the biggest cost. It’s murdering them [other stakeholders in the foundry industry] and us” – Participant 4

There was some contention from institutional participant 10, regarding whether electricity costs could be considered to be a legitimate sustainability issue for consuming industries. This was based on the premise that South African electricity costs are on par with global tariffs. However, participant 10 did appreciate that the energy intensity of the industry was an important issue due to the current utilisation of relatively inefficient technologies.

“People have not taken to heart issues of energy efficiency and investing in energy efficient technologies and now they have to catch up.” – Participant 10

Although the metal recycling industry is highly mechanised, energy was not a relevant issue for participants 2 and 3, due to the fact that they are not as reliant on electricity as an energy source. Instead, they are reliant on liquid fuels.

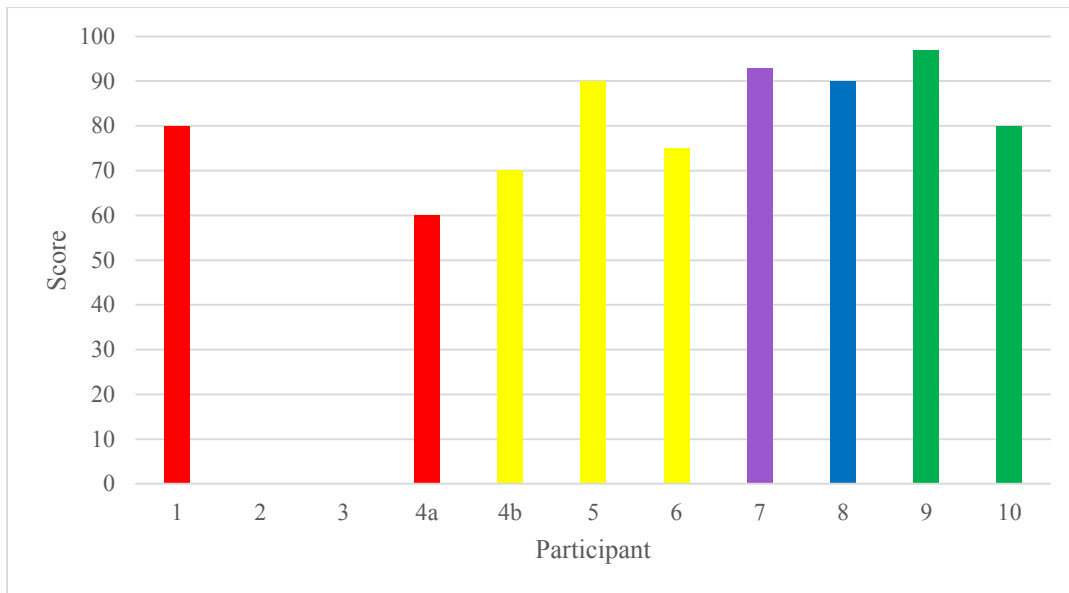


Figure 5-8: Scoring of the sustainability issue "energy"

5.3.2.9 Water management

The importance of water management varied amongst stakeholders, being generally not an issue for recyclers, but somewhat important to both foundries and steel mills.

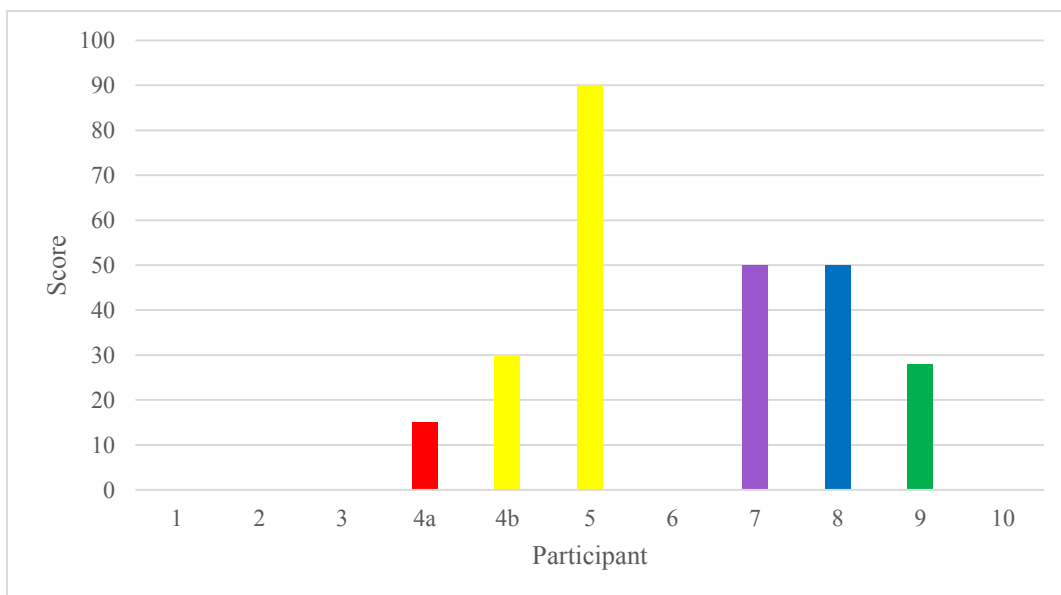


Figure 5-9: Scoring of the sustainability issue "water management"

5.3.2.10 Air pollution and climate change

Whilst air pollution and climate change were acknowledged to be important environmental concerns it received relatively low scores. The matter of atmospheric emissions was approached in relation to environmental legislative requirements regarding allowable emission levels for consuming industries. Compliance with these regulations often has financial implications increasing its relevance to decision-making. Scrap metal recycling is associated with relatively low atmospheric emissions due to the processes employed, which are primarily mechanical processes (e.g. sorting, cutting, shredding and

balancing). Consequentially, air pollution is a relatively insignificant factor for scrap metal recyclers in comparison with consumers.

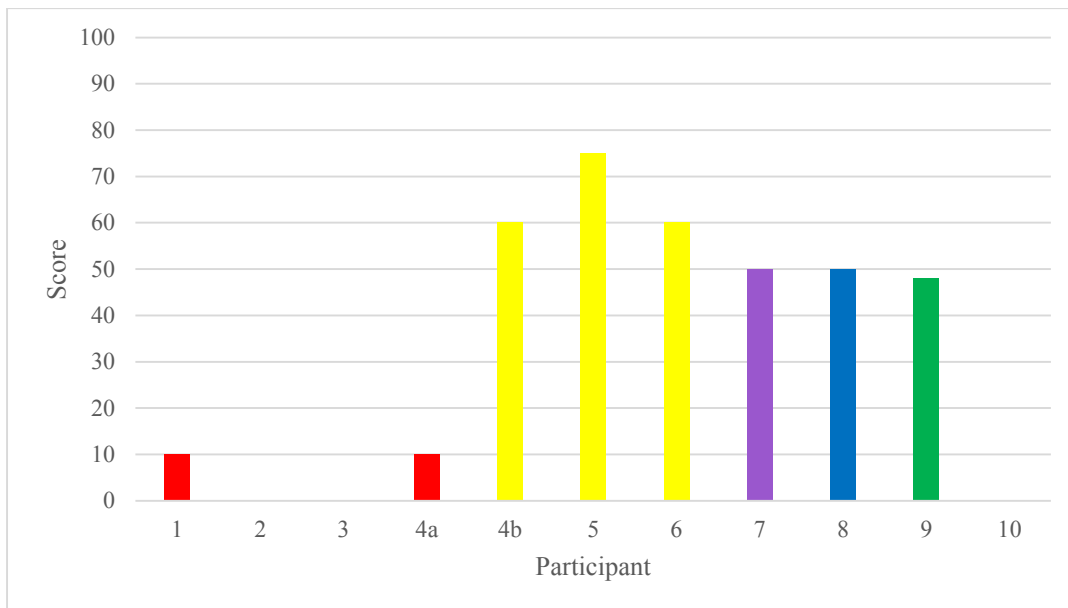


Figure 5-10: Scoring of the sustainability issue "air pollution and climate change"

5.3.2.11 Waste production

The production of solid waste and liquid effluents is an important consideration in the consuming industries. However, similarly to air pollution and climate change waste production was assigned low scores. The processing of scrap steel by recyclers is associated with relatively low waste production levels, due to both the processing techniques employed and the material that is processed. Recyclers will typically buy scrap from which they can obtain a high recovery of resalable material. This material will then undergo physical processing which is rarely associated with the production of any by-products. As such the industry is designed to operate with minimum waste production, with recyclers always looking to recover value from purchased scrap material.

The production and appropriate disposal of waste is an important consideration in the consuming industries. The introduction of more stringent environmental legislative requirements has put increased relevance of waste production particularly due to the cost implications of compliance, especially for stakeholders who do not have the financial means to comply. Therefore the importance placed on this issue is dependent on both the production methods used as well as the financial position of the firm. Steel mills have been placed under similar pressure since the introduction of the new environmental regulations which has necessitated the review of the waste streams produced and the manner in which they are disposed.

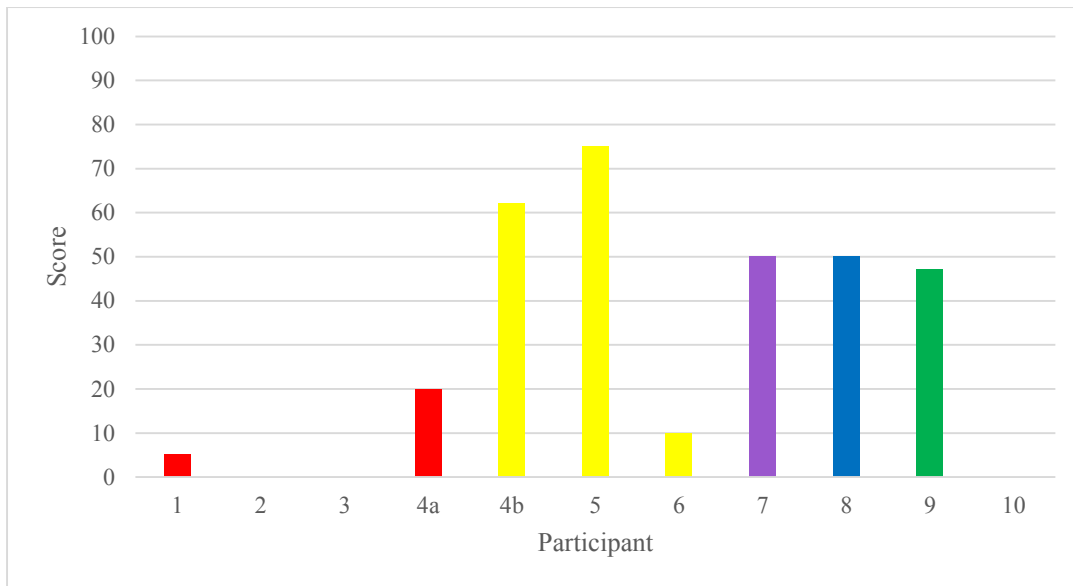


Figure 5-11: Scoring of the sustainability issue "waste production"

5.3.2.12 Job creation

The issue of job creation is a national concern and was considered relevant by both institutional participants. However, the level of relevance placed on it by industry participants became a matter of personal beliefs, with no apparent impact on the continued operation of their firms. The participants supported the drive for employment creation within the country and saw the role that each of their firms could play in promoting this. The metal recycling industry currently plays a major role in the informal economic sector with an estimated 400 000 informal traders participating in the collection of scrap for sale to scrap dealers and recyclers. A decline in the metal recycling industry poses a direct threat to the livelihoods of these traders. The scrap metal industry also plays a role in the formal employment sector, with the recent decline in the foundry industry leading to increased job losses. Therefore, the improvement in the performance of the industry is seen as integral to the promotion of job creation.

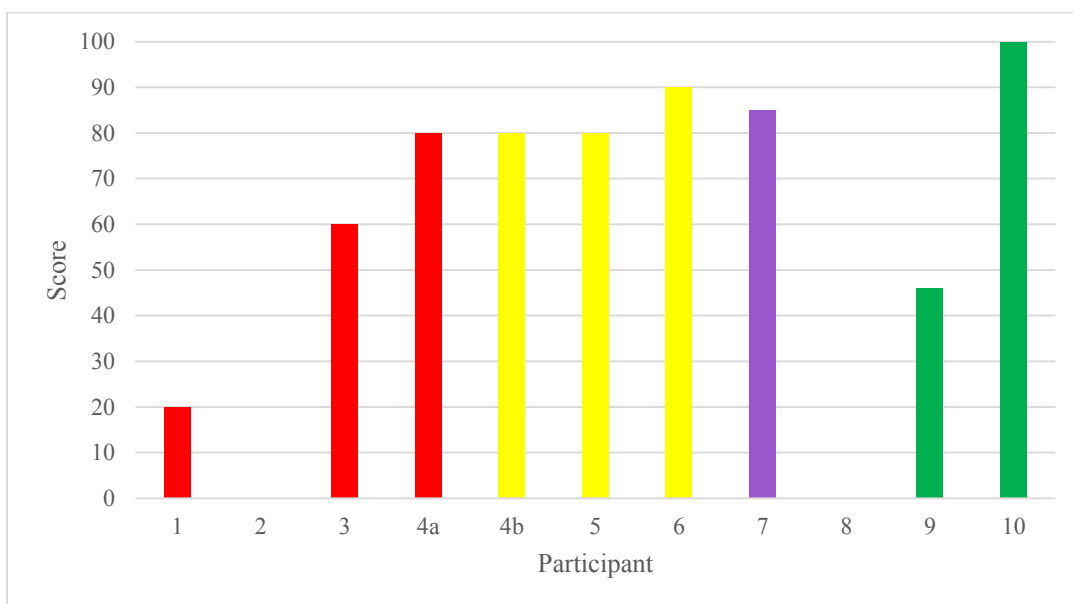


Figure 5-12: Scoring of the sustainability issue "job creation"

5.3.2.13 Skills availability

The relevance of skills availability is dependent on the skills profile of the industry. The consuming industries are especially affected by the nationwide skills shortages of artisans, technicians and engineers which are integral to their operations. The foundry industry is actively involved in skills development and training, with many employees trained via apprenticeships within the firm. The metal recycling industry absorbs a relatively larger proportion of unskilled labour, making it less vulnerable to the issue of skills availability. As such, it is not viewed as a relevant factor in decision-making. In the case of participant 4, skills availability was a concern in relation to mid- to high- level positions within the firm. Despite the skills shortage, participant 8 did not consider it to be of high relevance as the firm could simply import skills as needed. Institutionally, there are a number of skills development initiatives that are directed towards the metals and engineering sector. Although it was considered to be relevant, current structures in place were designed to address this issue in the long run.

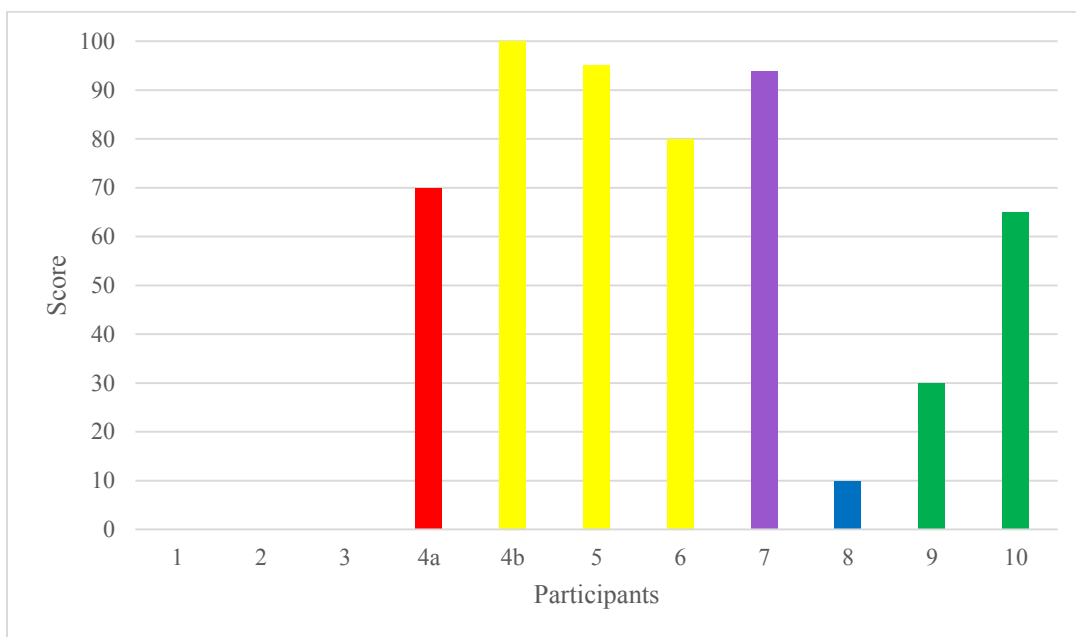


Figure 5-13: Scoring of the sustainability issue "skills availability"

5.3.3 Relative influence of sustainability issues

The scoring of sustainability issues makes it possible to explore the value systems of different stakeholders. It also enables the exploration of the relative influence of different sustainability issues on each participant's decision-making process. This was done by normalising the results of the scoring exercise, determining the fractional influence an issue had on the participant in question. The relative influence was compared according to the role the participants play in the scrap metal industry.

In the metal recycling industry, the relative importance assigned to different sustainability issues varied as illustrated in Figure 5-14. Participants 2 and 3 considered very few issues to be influential in their decision-making process. In contrast participants 1, 4 and 7 considered the majority of issues to be relevant albeit to varying extents. Participants 4 and 7 placed similar importance on micro-economic and socio-economic issues such as job creation and skills availability as well as access to raw materials. These similarities in their preference systems may be related to the fact that both participants are stakeholders in integrated firms, which both recycle and consume scrap metal. Market risk was the only

factor that was considered relevant by all participants, and was ranked highly by participants 1, 2 and 7. In the case of participant 2, market risk could be considered to be a determining factor in decision-making due to the level of importance it was assigned. It was one of two issues which the participant considered to be relevant of which the second issue (production costs) was assigned a relative importance of 0.09 in comparison. In cases where environmental and macro-economic issues were considered to be relevant, they were usually assigned relatively lower scores in comparison to other issues whilst micro- and socio- economic issues were on the higher end of the scale.

Although all foundry participants considered the majority of sustainability issues as relevant to the decision-making process, the variance in relative importance was more prominent in the foundry industry. As shown in Figure 5-15, few parallels could be drawn between the preference systems of the participants. The differences may be attributed to the different roles the participants play in the industry; participant 4 was a relatively new entrant in comparison to participant 5, whereby participant 6 was a representative of an industry organisation. However, there were some similarities in the ranking of issues, whereby profitability and skills availability were rated highly by all three participants. Similarities could also be drawn on the relative influence of energy on all three participants, which is to be expected due to high energy intensity of the industry.

In the steel mills, there were clear difference in the number of issues that the participants found relevant as shown in Figure 5-16. However, micro-economic issues such as production costs, profitability and market risk were found to be relatively more influential than other issues by both participants. Energy was also a highly influential issue in the decision-making process. Although both participants were representatives of the steel mills, there were fundamental differences in their firms; participant 8 represented a relatively large firm which primarily manufactures primary steel whilst participant 7 primarily produced secondary steel from scrap metal.

Institutionally, differences were observed in the number of issues the participants considered relevant as well as the relative influence assigned to different issues (Figure 5-17). This may be attributed to the different roles the participants play, whereby participant 9 was involved in development finance whilst participant 10 was engaged with trade and industry matters. Their different roles influenced their priorities and consequentially their value systems when it comes to the decision situation under consideration. However, production costs and access to raw materials were found to be relatively more influential than other issues albeit to varying extents.

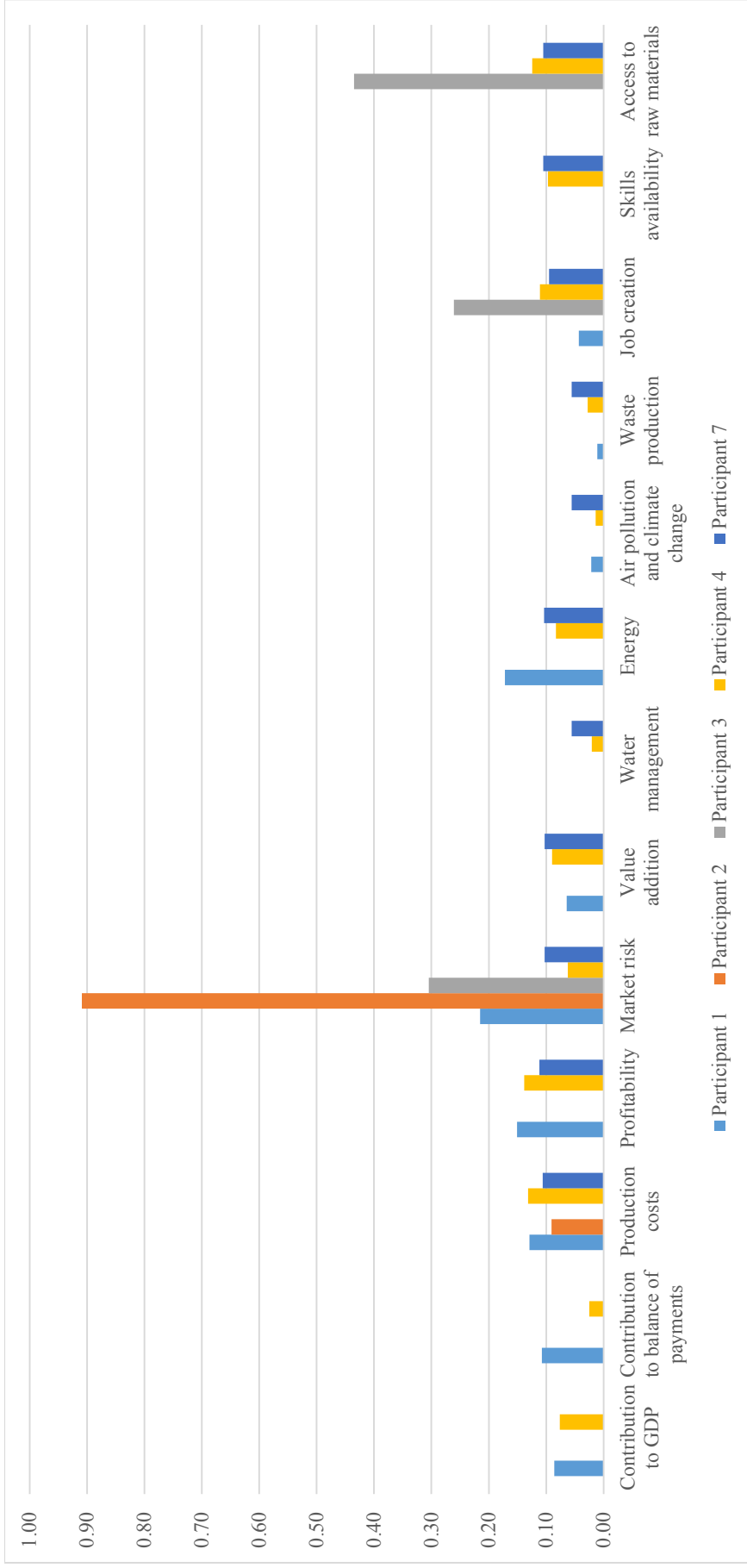


Figure 5-14: Relative influence of sustainability issues on metal recycling participants

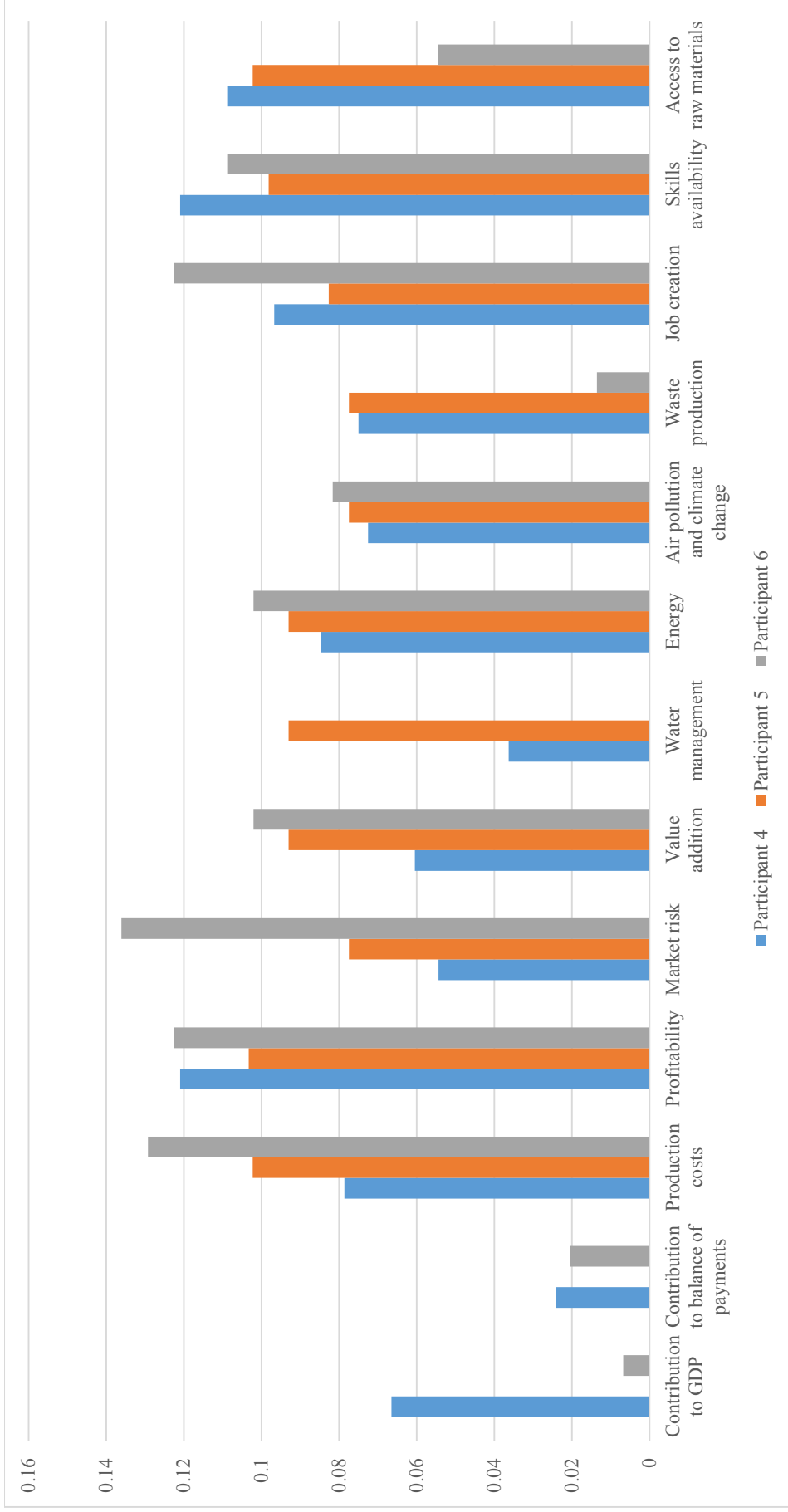


Figure 5-15: Relative influence of sustainability issues on foundry participants

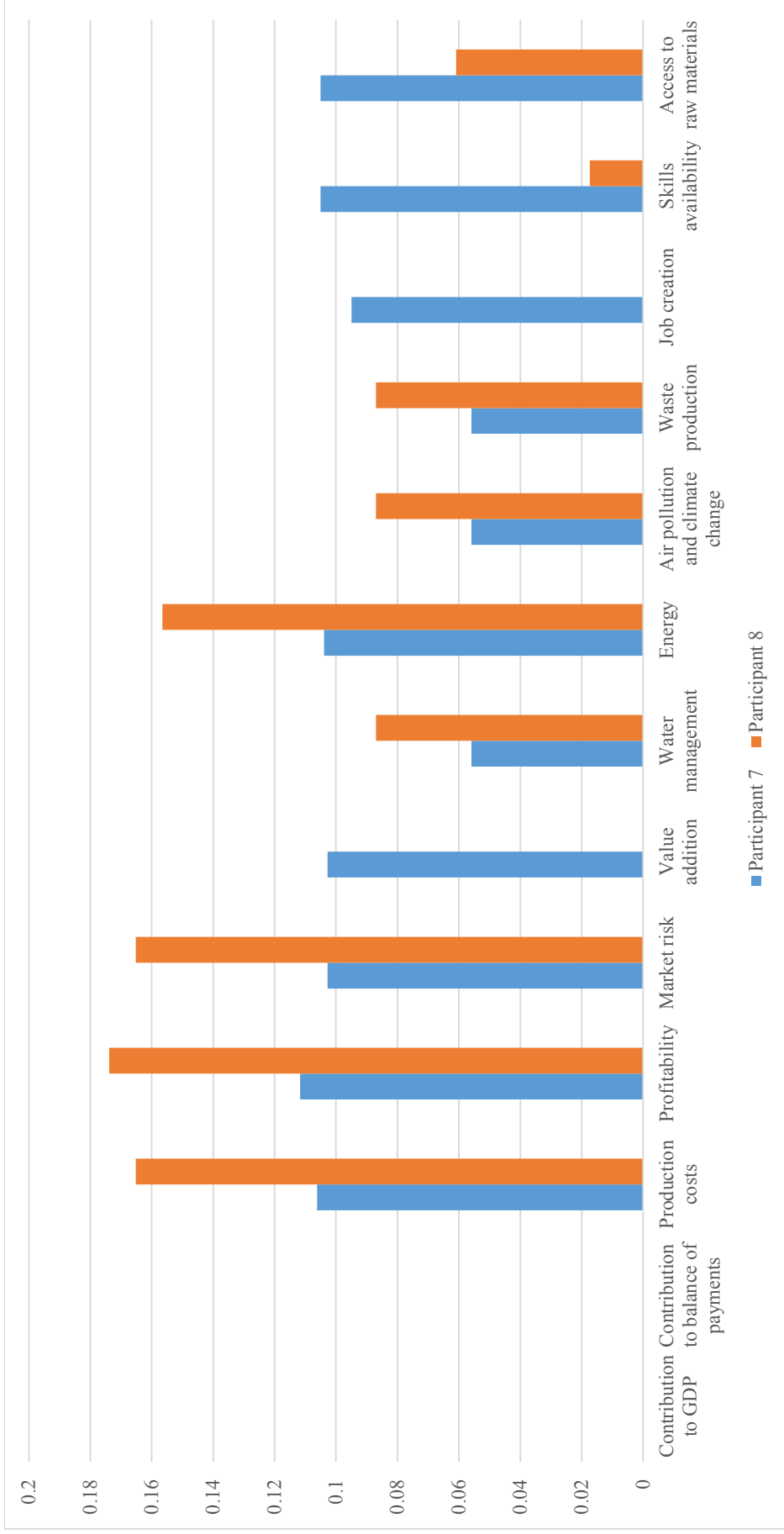


Figure 5-16: Relative influence of sustainability issues on steel mill participants

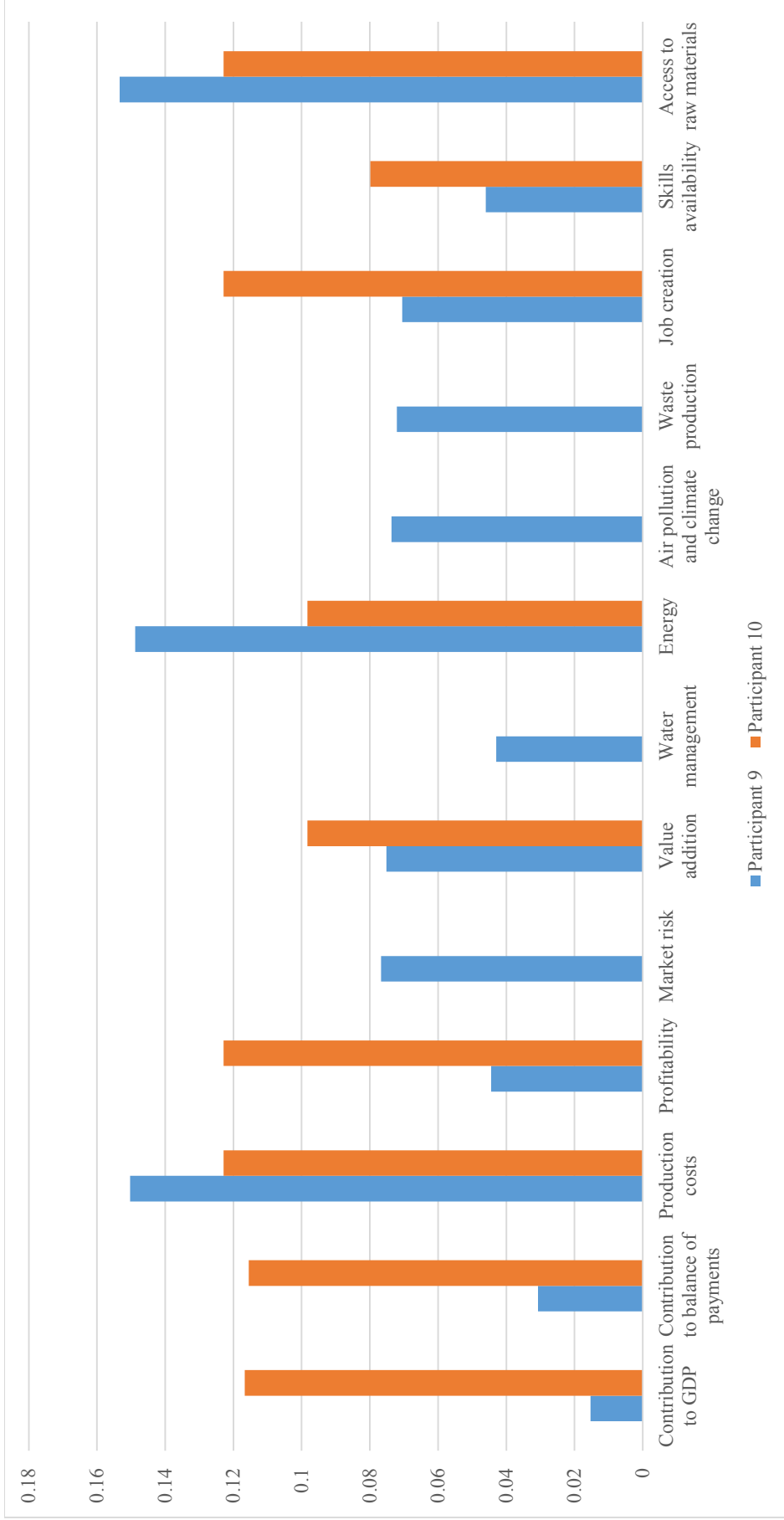


Figure 5-17: Relative Influence of sustainability issues on institutional participants

5.4 Summary

This chapter presented a discussion on stakeholder perspectives on the decision situation as well as an analysis of the relative influence of different sustainability issues on stakeholder decision-making. As discussed in section 5.2, none of the industry participants were against the export of scrap metal in principle. Instead their concerns surrounded the availability of good quality scrap suitable for processing in local industries. Furthermore, availability of scrap was considered to be one factor in a multiplicity of sustainability challenges currently being faced by scrap processors. When it came to levels of stakeholder engagement amongst stakeholders in the industry, discussed in section 5.2.3, there was a general sense of disgruntlement amongst the majority of industry participants regarding the current levels of engagement that exist between industry players and institutional entities. All industry participants agreed that meaningful stakeholder engagement was essential to promoting a deeper understanding of sustainability challenges being faced by the industry, and ultimately the formulation of strategies and/or policies that ensure sustainable development of the industry.

The results of the preference elicitation exercise, presented in section 5.3, showed stakeholder prioritisation of micro-economic issues directly related to the financial performance of the firm, such as profitability and production costs, when it comes to decision-making in this context. Although the importance of environmental issues was acknowledged, they were most likely to be ranked lowly in terms of importance, with their relevance commonly being viewed in terms of legislative requirements and corresponding financial implications. As shown in section 5.3.3, the relative influence of sustainability issues on the decision-making process differed amongst stakeholders, including those who play similar roles in the value chain. This may be attributed to a range of factors including the nature of the operations, business models, and the extent of their experience and involvement in the industry beyond their respective firms. Additionally, the personal principles of stakeholders also play a role as evidenced by the consideration of macro-economic issues that do not directly affect stakeholder firms. The influence of stakeholder value systems on alternative comparison is explored in section 6.3.

Chapter 6 Sustainability Performance Analysis of Alternatives for the Fate of Recycled Steel

It is a central objective of this dissertation to compare the alternatives according to key sustainability issues. These issues (as identified in section 4.4) were translated into quantitative and qualitative indicators (presented in section 0), against which the alternatives were evaluated and compared. This chapter presents the results of the sustainability performance evaluation of the alternatives and their comparison. This is followed by a discussion surrounding the potential impacts of stakeholder value systems, as determined in section 5.3, on alternative comparison and ultimately the decision-making process in general.

6.1 Alternative Evaluation

The sustainability performance of the three different alternatives for the fate of recycled scrap was evaluated for the year 2013. In cases when the 2013 figures were unavailable, estimates were based on the most recent data or drawn from literature sources. Details of all assumptions made as well as data sources are available in Appendix H. The results of the alternative evaluation are presented in Table 6-1.

Table 6-1: Sustainability performance assessment of decision alternatives

Aspect	Issue	Indicator	Unit	Decision Alternative			
				Export	Steel Mill	Foundry	
Access to raw materials	Capacity	Amount of product	kilotonnes	1 620	7 160	343	
	Access to raw materials	Total amount of ferrous scrap metal generated in South Africa	kilotonnes		3 500		
Contribution to economic development	Contribution to GDP	Amount of scrap consumed	kilotonnes	1 620	1 420	453	
	Contribution to balance of payments	Direct contribution to GDP	R (billion)	0.93	5.83	2.23	
Economic performance	Contribution to balance of payments	Contribution to balance of payments	R (billion)	5.4	1.9	7.9	
	Production costs	Production costs	R/ t product	-	5 930	14 000	
	Value addition	Sales value of commodity	R/t product	3 530	7 680	18 100	
	Profitability	Gross profit margin	%	10	29.6	29.4	
	Market risk	Proportion of product currently imported	%	n.a.	23.6	12.1	
	Energy	Energy	electricity consumption	GJ/t molten metal	-	1.5 - 4.2	3.1 - 8.6
	Environmental performance	Water management	Water consumption	m ³ /t molten metal	-	3.1 - 4.1	20
Air pollution and climate change		Direct CO ₂ emissions	tonnes CO ₂ /t molten metal	-	2.3	minor	
		NO _x emissions	kg/ t molten metal	-	4.2	minor	
		SO _x emissions	kg/ t molten metal	-	4.6 - 7.5	<1	
		Particulate Matter	kg/ t molten metal	-	0.08 - 2.8	0.04 - 8	
Waste production		Total weight of effluents and waste produced	kg/ t molten metal	-	231	300 - 500	
Job creation	Labour intensity	employment/ kilotonne of product	-	3.2	24.3		
Socio-economic performance	Skills availability	Proportion of jobs requiring skilled labour	description	-	majority skilled with some semi-skilled	majority semi-skilled with a mix of skilled and unskilled	

6.2 Alternative Comparison

This section compares the performance of alternatives, according to the results presented in Table 6-1.

6.2.1 Access to raw materials

In 2013, approximately 3 500 kt of ferrous scrap metal was generated of which 46% was exported whilst 41% and 13% was consumed in the steel mills and foundries respectively. The fact that the consuming industries only consumed 54% of generated scrap points to industry capacity as a potential constraint to the increase of local scrap consumption. The consumption of scrap is also constrained by the technology that is employed by the industries as this directly influences the grade and quality of scrap that can be processed efficiently. The difference in the amount of scrap diverted to the foundry industry and the final product output can be attributed to metal losses at various stages in the process. The yield of metal in a casting process is dependent on a number of factors including the melting and casting processes employed (Fore & Mbohwa 2010). Although steel mills produce that largest quantity of final product, it is not possible to differentiate how much of that product is purely secondary steel. Steel mills produce a combination of primary and secondary steel products, of which varying levels of scrap may be used in both processes. Therefore, an increase in the consumption of steel in this industry will not necessarily result in a marked increase in the amount of product, as manufacturers may simply opt to increase the proportion of steel scrap in the products.

6.2.2 Contribution to economic development

Steel mills account for a significantly larger direct contribution to GDP of R 5.83 billion, in comparison to R 2.2 billion and R 0.93 billion resulting from foundry and export activities respectively. Although the foundry industry produces higher value commodities, the large capacity of the steel mills results in increased total revenues. With regards to contribution to balance of payments, foundries contribute the most with R 7.9 billion, followed by scrap exports with R 5.4 billion. The relatively low contribution by steel mills (R 1.9 billion) may be attributed to the relatively large value of primary steel product imports which results in a smaller contribution to balance of payments.

6.2.3 Economic performance

Amongst the three alternatives, foundries produce significantly higher value commodities and as such are associated with higher production costs. Despite differences in costs structures, consuming industries have similar gross profit margins.

Almost 25% of steel mill products on the domestic market in 2013 were imported which is an indication of the decreased competitiveness of local products. Although a lower proportion was reported for the foundry industry this may not be an accurate representation of the overall domestic market share due to the form in which castings are imported into the country. Often castings produced elsewhere are not necessarily imported individually, but as components of a preassembled product. Importing such products decreases the local demand of castings which formed components of the product had it been assembled locally, for example, in the case of engine blocks.

6.2.4 Energy

The iron and steel industry is highly energy intensive. Steel processing in particular is associated with high energy consumption in general, and electricity demand in particular. This intensity is dependent on the technology employed. Secondary steel production from scrap utilises electric arc furnaces which

are dependent on electricity. In contrast, primary steel manufacturing processes, which require more energy overall since iron ore must be reduced to the metallic state, typically utilise blast oxygen furnaces in steel production. Therefore, secondary steel production has a higher electricity consumption (approximately 4.2 GJ/t steel) in comparison to primary steel production (1.5 GJ/t steel). The majority of foundries utilise electric induction furnaces whilst a small proportion utilise electric arc furnaces. However, inefficiencies in the industry have the potential to greatly escalate electricity consumption as reflected in the consumption range of 3.09 – 8.64 GJ/ t steel. The high consumption in foundries can be remediated by implementing measures to reduce energy loss and wastage, such as increasing furnace insulation or installing a lid to reduce losses from the metal surface (Reinhardt 2011).

6.2.5 Environmental performance

Whilst in the port, the scrap does not undergo any further physical and/or chemical processing prior to exporting. Thus in this case, there are no associated direct environmental impacts. In essence the environmental impacts associated with scrap processing are exported to the destination.

The environmental impacts associated with any process are highly dependent on the technology employed as well as the efficiency of the process. On average, foundries consume significantly more fresh water than steel mills. Within the steel mills, processes producing secondary steel from scrap metal consume less water (3.1 m³/ t molten metal) than those producing steel from iron ore (4.1 m³/ t molten metal).

In terms of atmospheric emission, steel mills are generally associated with greater negative impacts. The use of coke as an energy source and reductant in iron ore processing results in average direct CO₂ emissions of 2.3 t CO₂/t molten metal, which is avoided in secondary steel mills. In contrast, the foundry industry is associated with minor emissions of CO₂ which may result from the casting process. Instead, carbon is commonly emitted in the form of CO in levels ranging from 7.5 – 25 kg/ t molten metal. As scrap metal processing is reliant on electricity as an energy source, this results in indirect CO₂ emissions as a consequence of the coal used in power generation. As foundries generally consume more electricity than steel mills they are associated with greater indirect CO₂ emissions.

As can be seen in Table 6-1, steel mills are associated with higher emissions of the SO_x and NO_x, in comparison to foundries. Minor NO_x emissions from foundries may be resultant from casting and pouring activities. Emissions of particulate matter are major concern throughout the foundry process. Of particular concern is the presence of hazardous substances in the emissions, including heavy metals and volatile organic compounds (Fatta et al. 2004). The emission of these contaminants is also associated with liquid effluents and solid waste discharged from the process. Their concentration varies depending on scrap composition and furnace additives (Fatta et al. 2004).

6.2.6 Socio-economic performance

Steel mills contribute more to employment with 23 000 employees, compared to 8 320 employees associated with foundries. However, when this is expressed as labour intensity the inverse is true. The foundry industry creates significantly more jobs per tonne of commodity produced. This implies that an increase in foundry capacity will have a greater impact on employment creation than increased capacity in steel mills. In terms of skills profiles, the foundry industry employs a more diverse

workforce in comparison to steel mills. Furthermore, foundries have a greater capacity to absorb unskilled labour as many employees are upskilled on the job.

6.3 Potential Impacts of Stakeholder Value Systems on Alternative Comparison

As can be seen from the alternative comparison, decision-making in this context would invariably require trade-offs to be made between criteria. The relative influences of different sustainability issues on stakeholders, ascertained in section 5.3, can be used to explore the potential impacts of stakeholder value systems on the decision-making process. The preference elicitation exercise determined that stakeholders were most likely to prioritise micro-economic issues when making decisions in this particular context. When evaluated according to these most influential factors, as determined in section 5.3.1, the results of the sustainability performance assessment show steel mills as out-performing the other alternatives. Steel mills (of the integrated type) are not as reliant on scrap a primary raw material, reducing its impact on operations. The use of iron ore as a primary raw material in many operations also reduces steel mill dependence on electricity, which reduces vulnerability to the electricity crisis relative to foundry industry. Furthermore, in 2013 steel mills managed to achieve a gross profit margin of 37%. However, when the alternatives are compared according to their environmental performance, the comparison is more complex. Scrap exporting results in shifting the burdens associated with processing to the destination. In the cases of the consuming industries, steel mills are associated with significantly higher CO₂, NO_x and SO_x emissions but lower emissions of particulate matter. Socially, foundries provide more benefits with a higher employment intensity coupled with a diverse skills profile.

As can be seen from the discussion above, the consideration of stakeholder value systems in isolation, during the decision-making process, has the potential to side-line significant sustainability issues. This can ultimately lead to distortion of the performance assessment of the alternatives under consideration, leading to decision-making which may unwittingly result in outcomes with dire consequences. In this specific case, where micro-economic issues were prioritised, consideration of these factors in isolation may lead to an alternative being chosen which is associated with greater negative environmental impacts and lower employment creation potential.

6.4 Summary

This chapter presented the results of the sustainability performance evaluation of the decision alternatives under consideration, followed by their comparison. The comparison showed the complexity associated with multiple criteria decision-making, evidenced by the fact that no alternative consistently performed best across all indicators. This points to the need for trade-offs to be made when making decisions in this context. This chapter also discussed the potential impact of stakeholder value systems on the decision-making process. The consideration of stakeholder priorities in isolation, when it comes to sustainability performance analysis, has the potential to side-line significant sustainability issues. This may lead to trade-offs being made which may have dire consequences.

Chapter 7 Discussion and Conclusions

Chapters 4 to 6 presented and analysed the results of the application of a generic DSF on the South African iron and steel scrap industry, particularly the decision surrounding the fate of recycled scrap metal. Chapter 4 served to provide an understanding of the decision situation by presenting a background to the industry based on desktop research. This included definition of the alternatives under consideration and the identification of key sustainability issues within the industry. In Chapter 5, stakeholder perspectives on the decision situation were explored as well as their value systems regarding the relative influence of different issues on their decision-making process. Chapter 6 presented the results of the sustainability performance of the decision alternatives as well as their comparison.

The purpose of this chapter is to consolidate the results presented in Chapters 4 to 6 and discuss their implications. The first section provides a summary of the relative influence of different factors on decision-making in this context, based on stakeholder preferences elicited in Chapter 5. This is followed by a discussion on the potential impacts of stakeholder value systems on alternative evaluation and comparison, which inherently emphasises the importance of stakeholder selection and engagement in the decision-making process. The implications of the study are discussed in the context of the objective of this dissertation, which sought to investigate the applicability of DSFs for sustainability performance analysis and comparison of decision alternatives for minerals beneficiation. The chapter concludes with recommendations for future work surrounding the application of decision support frameworks for strategic planning in the minerals sector.

7.1 Key Factors in the Decision-Making Process

Research conducted prior to stakeholder consultation yielded a list of thirteen sustainability issues currently affecting the iron and steel scrap industry (presented in section 4.4). These included social, environmental and economic dimensions of sustainable development. The identification of these issues was based on desktop research into the current status quo of the industry after which they were legitimised during the stakeholder consultation process. When these issues were presented to stakeholders during the preference elicitation phase, it was found that issues that directly impacted the financial performance and sustainability of the firm were most likely to be prioritised during the decision-making process. More specifically, these included micro-economic issues integral to the financial health of a firm namely, production costs, profitability and market risk. Inputs that were vital to the functioning of the business were also considered to be highly relevant in the decision-making process, including access to raw materials and energy. Energy was viewed both from a financial perspective in terms of rising electricity costs and as vital input to production processes in light of the threat to supply presented by the recently experienced implementation of load-shedding. Less emphasis was placed on environmental issues, when it comes to their relative influence on the decision-making process. Furthermore, environmental issues were often viewed in terms of the financial implication associated with compliance with environmental legislation.

7.2 Stakeholder Influence on Sustainability Performance Evaluation and Comparison of Decision Alternatives

As discussed in section 6.3, the prioritisation of one dimension of sustainability (in this case micro-economic issues) has the potential to side-line significant sustainability issues in other dimensions. Thus sustainability performance analyses based purely on issues prioritised by stakeholders may lead to

distortion of the sustainability performance evaluation of decision alternatives. For example, an evaluation based purely on economic indicators may lead to an alternative being chosen which may have high negative environmental impacts and/or lower socio-economic benefits. Ultimately, the structured approach to sustainability performance assessment provided by DSFs ensures consideration of sustainability impacts, across all dimensions of sustainable development. Although stakeholders will undoubtedly be influenced by their value systems, presentation of the wide range of sustainability issues during the consultation phase forces them to engage with issues that may not have necessarily come to mind intuitively. Furthermore, evaluation of alternatives according to their performance across all identified sustainability indicators increases the likelihood of factors being taken into consideration during the decision-making process which may have been ignored otherwise.

7.3 Importance of Meaningful Stakeholder Engagement in Decision-Making

The findings of the case study confirmed the importance of meaningful stakeholder engagement throughout the decision-making process. As discussed in section 2.3.2, stakeholder engagement has previously been reported to be an important and integral element of decision-making which applies legitimacy to the process (Basson & Petrie 2001; Veleva & Ellenbecker 2001; Hilson & Basu 2003; Azapagic 2004; Bell & Morse 2008).

Whilst Chapter 4 served to provide a general understanding of the decision situation, including associated sustainability issues, it did not provide much insight into the current situation on the ground. More specifically, it did not identify the relationships that exist between stakeholders as well as any specific challenges they were facing. The results of the stakeholder consultation process, presented in Chapter 5, provided a more in-depth understanding of the decision situation beyond what was reported in literature and main-stream media. The analysis of different stakeholder perspectives provided insights into the complexities that exist within the industry, including stakeholder relationship dynamics. This is particularly important in decision-making situations characterised by multiple decision-makers who commonly have conflicting preferences and objectives (Azapagic & Perdan 2005a).

A key aspect of stakeholder engagement is the identification of stakeholders, which is particularly complex with regards to how stakeholders are to be represented (Petrie et al. 2007). As observed in section 5.3.3, whilst there was a fair bit of alignment in stakeholder priorities, some variations were observed amongst stakeholders who played similar roles in the value chain. For example, in the metal recycling industry there were some stark differences in the relative importance placed on different factors when it came to decision-making in this context. However, as discussed in section 7.1., there were some key factors that were deemed relevant across the industry. Stakeholder value systems may be influenced by a range of factors, including the nature of their operations, the extent of their experience and involvement within the industry beyond the scope of their firm, as well as the relationship dynamics that exist between them and other stakeholders. The personal principles of stakeholders also play a role, which is particularly evidenced by the consideration of issues that do not directly affect stakeholder firms during the decision-making process. For example, the majority of industry stakeholders did not consider “contribution to GDP” as relevant to their decision-making process. Those who did consider it relevant spoke of their desire to see and contribute to national economic growth. Although the engagement process only considered a sample size of ten participants, the results showed a range of opinions within the industry. An increase in the sample size could

potentially bring more perspectives to light which may or not correlate with the value systems outlined in Chapter 5. This case study illustrated the complexity associated with ensuring stakeholder representation, due to the multitudes of perspectives that could potentially exist.

7.4 The Potential Role of Decision Support Frameworks in Strategy Development in the Minerals Sector

DSFs have the potential to play a valuable role in strategic planning in the minerals sector, particularly in the sustainability performance analysis and comparison of decision alternatives for minerals beneficiation (Azapagic & Perdan 2005a; Petrie et al. 2007). However, the extent to which they are applicable is dependent on a number of factors including the decision situation and the objectives of the process. The following sections discuss how the findings of this case study point to the extent to which DSFs may be applicable for strategy development in the minerals sector. The findings are discussed in reference to the two main research questions, presented in section 3.1, which guided this dissertation:

- 1. What could be learnt from applying a decision support framework on a constrained sub-sector that could possibly be applied to other sectors or on a larger scale?*
- 2. Would the application of a decision support framework be beneficial in the development of a mineral beneficiation strategy?*

7.4.1 Key learnings from the application of a DSF on the iron and steel scrap industry

This dissertation explored the application of a generic DSF on an existing industry, with each of the alternatives under consideration being in existence. As shown in the findings, the application of DSFs in this context provides a realistic perspective on the current status quo within an industry enabling an analysis of the health of an industry. However, as shown in section 6.3, the comparison of decision alternatives is a complex process which commonly requires trade-offs to be made. The structure of DSFs enables decision-makers to develop an understanding of the different decision criteria being taken into consideration. This understanding is particularly important when it comes to determining the implications of making different trade-offs, especially when it comes to factors where a relatively bad performance can be remediated, effectively increasing the potential long-term sustainability benefits associated with an alternative. Therefore, DSFs facilitate informed decision-making based both on the current status quo of the industry and long-term potential sustainability benefits that could be realised from changes being made in the industry.

In order for long-term maximum sustainability benefits to be realised it may be necessary for strategies to be developed to remediate any challenges and/or threats an industry may be facing. The stakeholder consultation process makes it possible to investigate the underlying complexities and factors that contribute to different issues. It also enables the exploration of how different stakeholders are affected by a particular issue, and their perspectives on possible remediation options. This encourages and facilitates analysis of issues from different perspectives resulting in a deeper understanding of the impacts of an issue across an industry and potential routes for remediation. Ultimately this enables the development of well-informed targeted strategies and policy interventions that take into consideration different stakeholder perspectives increasing the likelihood of their success.

In the particular case of the iron and steel scrap industry, a policy intervention was implemented regarding the export of scrap in a bid to increase availability to local consuming industries and

ultimately increase their productivity (discussed in section 4.2.2). Although the policy was developed with good intentions it has been met with some contention from stakeholders. As discussed in section 5.2.2, stakeholders were of the opinion that the policy was not effectively tailored so as to achieve its intended objectives, pointing to insufficient stakeholder consultation. Furthermore, when viewed in the greater scope of the challenges currently facing the consuming industries, stakeholders did not believe that the intervention was well suited to address their current decline. The structure of the DSF enabled the identification and exploration of sustainability challenges being faced by the industry as well as stakeholder perspectives regarding the relative importance of these issues (presented in Chapter 5). As discussed in section 5.2.3, all industry stakeholders believed that there was a need for increased meaningful stakeholder engagement between industry and institutions in order to facilitate the formulation of strategies and policies that would ensure the growth of the industry. Although the application of DSFs in this dissertation did not culminate in the choice of an alternative, some valuable insights were gained that could be used in the remediation of current challenges being faced across the iron and steel industry. More specifically, the value of a DSF in this context can be considered to lie at the tactical level where the 'how' of an intervention is likely to be better aligned with the realities of an industry.

7.4.2 Application of decision support frameworks in mineral beneficiation strategy development

As mentioned in the background to this study (presented in Chapter 1), many countries are looking to promote downstream mineral beneficiation activities in the hopes of increased socio-economic growth. In many instances this involves the establishment of new industries with mixed results, as seen in the cases of Zimbabwe and Botswana reviewed in section 1.1.2. Such strategic decisions are commonly associated with large spatial domains, long time frames and a diverse group of stakeholders which has a bearing on the tools and assessment criteria used (Basson & Petrie 2001; Notten 2001). Furthermore, the strategic context is associated with high levels of uncertainty due to the type of information available (see section 2.3.1). It is often necessary to predict relevant data which increases in uncertainty as the time frame increases (Notten 2001).

As shown in Chapter 6, the sustainability performance assessment conducted as part of the DSF can give a good indication of the potential sustainability benefits that may be obtained from pursuing an alternative. However, the robustness of decisions made based on this assessment is highly dependent on the level of uncertainty associated with the information used to inform the indicators. The complexity introduced in evaluating indicators which are greatly influenced by external factors (beyond the control of the decision-makers) increases the level of uncertainty in the decision-making process. This is particularly characteristic of economic indicators which are often influenced by a myriad of local and global factors. In the case of the iron and steel scrap industry, stakeholders in the consuming industries cited competitiveness on the global market as a key challenge (discussed in section 5.2.1). The importance of a secure market for goods was also emphasised by stakeholders as essential to the success of an industry (section 5.3.2.7). However, the potential market share is dependent on a multitude of factors including global competitiveness and trade agreements. Such factors are difficult to control locally, as they are influenced by the socio-economic and political landscapes of different locales. In contrast, factors which are dependent on processing routes can be predicted with relatively more precision, e.g. environmental impacts. Although DSFs allow for the consideration of uncertainty in

testing the robustness of decision made, this aspect what not explored in this dissertation. In addition, this dissertation did not explore the integration of decision support tools, such as scenario analysis, which may assist in developing a more realistic perspective on the potential sustainability performance of an alternative. Therefore further research is required to investigate the applicability of DSFs in the development of mineral beneficiation strategies.

7.5 Conclusion

This chapter consolidated the results presented in chapters 4 to 6 and provided a discussion on their implications in relation to the applicability of DSFs for strategic planning in the minerals sector. The importance of stakeholder engagement was a recurrent theme in the discussion. Although stakeholder preferences have the potential to result in sustainability issues being side-lined, the structure of DSFs ensures consideration of all issues. Overall, the results indicated that DSFs have the potential to play an important role in strategic planning in the minerals sector, however the extent of their effectiveness is highly dependent on the decision situation and the objectives of the process. As discussed in section 7.4.1, DSFs facilitate informed decision-making that takes into consideration potential long-term sustainability benefits in existing industries. Furthermore, through stakeholder engagement it is possible to gain a deeper understanding of sustainability issues and their effects, enabling the development of effective policies to remediate them.

This dissertation did not produce any conclusive findings with regards to the applicability of decision support frameworks for the development of mineral beneficiation strategies, particularly for the establishment of new industries.

7.6 Recommendations for the Application of Decision Support Frameworks in the Minerals Sector

Based on the conclusions arrived at in the case study developed in this dissertation, it is recommended that difficult and contested policy decisions in mineral beneficiation be informed by robust stakeholder engagement processes. In particular, the elicitation of stakeholder preferences is an additional practice that is recommended. Furthermore, it is recommended that the formal structure presented by DSFs be followed as it ensures explicit consideration of all sustainability issues. This enables a comprehensive analysis of the health of an industry beyond the scope of stakeholder priorities.

7.7 Recommendations for Future Work

Whilst it has been determined that decision support frameworks could potentially play an important role in decision-making for minerals beneficiation more research needs to be conducted regarding their applicability in the development of mineral beneficiation strategies. As discussed in section 7.4.2, decision-making in this context is associated with high levels of uncertainty. Therefore, research should be conducted in the management of uncertainty in the decision-making process (discussed in section 2.3).

Although DSFs are commonly underpinned by MCDA to facilitate and support the decision-making process, this dissertation did not explore the selection and application of MCDA techniques (as discussed in section 3.3). Research into the integration of MCDA techniques in the application of DSFs in this context would provide a more structured approach to alternative evaluation and comparison which takes into consideration stakeholder perspectives. Furthermore, they provide information in a

succinct and comprehensible form which assists in the selection of a preferred alternative (Belton & Stewart 2002; Hajkowitz 2007; McLellan et al. 2009). An overview of MCDA techniques as well as their characteristics is available in Appendix B.

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Appendix A Sustainability Indicator Frameworks

There are a number of integrated sustainability indicator frameworks that are designed for application at different spatial and temporal levels, i.e. international, national, local and corporate level indicators. This section includes a review of corporate frameworks by the Global Reporting Initiative (GRI), the Institute of Chemical Engineers (IChemE) as well as those by researchers Azapagic (2004) and Labuschagne et al. (2005).

Global Reporting Initiative

In 1997, the United Nations Environmental Programme (UNEP) together with the Coalition for Environmentally Responsible Economics (CERES), which is a United States nongovernmental organisation launched the Global Reporting Initiative (Labuschagne et al. 2005). GRI uses a hierarchical framework which consists of categories, aspects and over 100 quantitative and qualitative indicators. However, there is no guidance provide on how to select between indicators and evaluate them (Veleva & Ellenbecker 2001). The goal of the GRI was to enhance the quality, rigor and utility of sustainability reporting, therefore reporting is a strong focal point of the guidelines (GRI 2000). The GRI approach to reporting can be used in conjunction with other frameworks for sustainable development. For example, organisations may choose to adopt the five capitals approach to sustainable development yet still utilise the GRI Guidelines to reporting. This approach is supported by the SIGMA Project (2003) in the assertion that the GRI approach is ‘consistent and complementary’ with SIGMA’s approach to sustainable development.

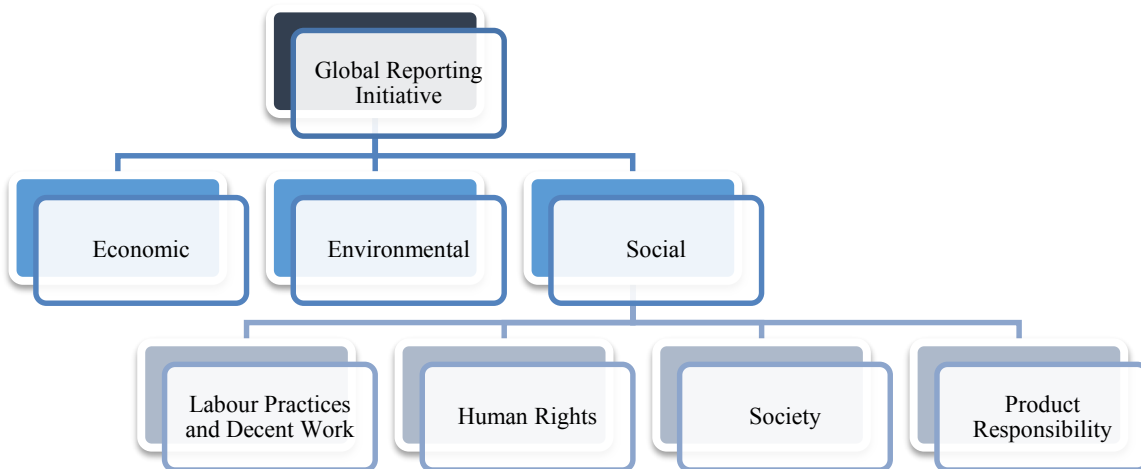


Figure A-1: The Global Reporting Initiative Framework (GRI 2013b)

GRI Mining and Metals Sector Disclosures

A significant number of companies within the minerals sector are reporting according to the GRI framework (Petrie et al. 2007). In 2010 the GRI launched the ‘GRI Mining and Metals Sector Supplement’ containing a set of disclosures that are meaningful to the mining and minerals sector and are not covered within the guidelines (GRI 2013a). The supplement was developed in conjunction with the ICMM as co-convener, and the pilot version was launched in 2003 followed by a final version in 2010. The main contextual issues in the supplement include:

- Control, use and management of land
- Contribution to national economic and social development
- Community and stakeholder engagement
- Labour relations
- Environmental management
- Relationships with artisanal and small-scale mining
- An integrated approach to minerals use

However, the disclosures are targeted towards the primary mining and metal processing sector including smelting, recycling and basic fabrication (GRI 2013a).

Sustainability Metrics of the Institution of Chemical Engineers

In 2002, the Institute of Chemical engineers published a set of sustainability indicators tailored towards operation within the process industry. Similar to the GRI, the IChemE framework is based on the triple bottom line approach to sustainable development with the indicators organised according to economic, environmental and social aspects (IChemE 2002). Although the framework is designed for internal use IChemE encourages assessment publication utilising a reporting format that is consistent with that of the GRI. Although the framework is less complex and impact oriented, it strongly favours environmental aspects as well as quantifiable indicators that may not be practical particularly in the early stages of a project (Labuschagne et al. 2005). The framework does not require a life cycle approach to the assessment and instead focuses on a company’s direct activities, i.e. from ‘gate-to-gate’. This weakness means that sustainability impacts associated with other parts of the supply chain could be missed in an assessment.

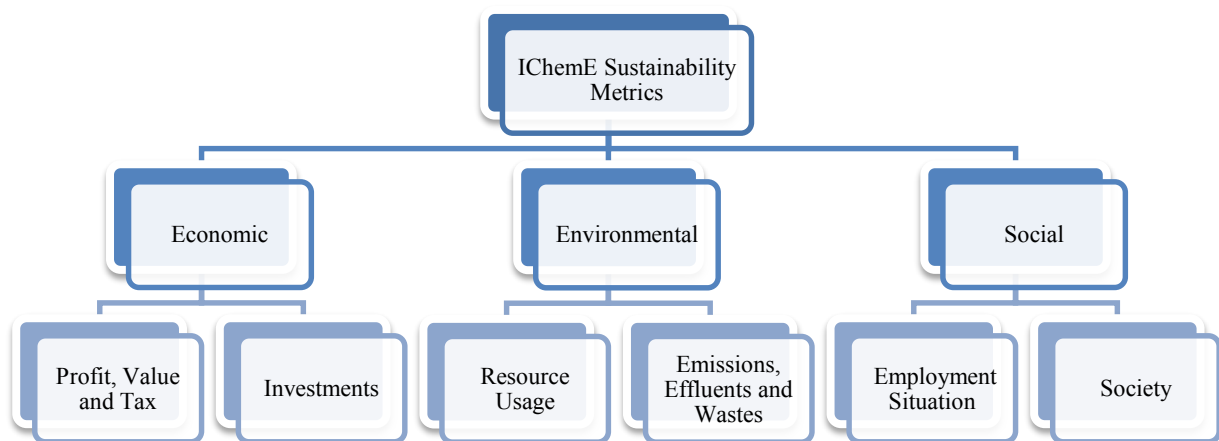


Figure A-2: The IChemE Sustainability Indicator Framework (IChemE 2002)

Azapagic & Perdan's sustainability indicator framework for industry

In 2000, Azapagic and Perdan proposed a general framework for measuring sustainability in industry across the three dimensions of sustainable development – environmental, economic and social. The framework was developed to be applicable across industry however it was recommended that sector specific indicators be developed as required. It takes both a micro- and macro- approach to sustainable development, through the development of appropriate indicators. A life cycle approach was utilised in

the development of the framework, whereby the assessment takes into consideration the full supply chain from ‘cradle to grave’.

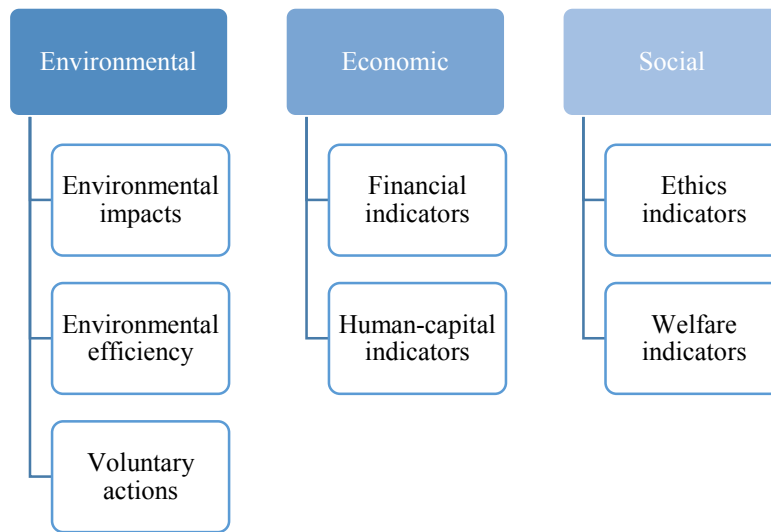


Figure A-3: Azapagic and Perdan's proposed framework for industry (2000)

The proposed indicators are classified into categories within the different aspects of sustainable development as shown in Figure A-3. Environmental impact indicators are based on categories that are commonly included in life cycle assessments. Environmental efficiency takes into consideration the material and energy efficiency as well as recyclability in the case of product evaluation (Azapagic & Perdan 2000). However, the applicability of efficiency may be constrained by the type of assessment, i.e. whether it is a product, process or industry evaluation. The framework also evaluates a firm’s dedication to environmental sustainability through its assessment of environmental strategies under the “voluntary actions” category. Beyond the financial indicators commonly included in assessing the economic performance of a firm, the framework also takes into consideration indicators of human capital which are focused on issues related to employees. This category includes indicators related to investment in staff development and staff turnover (Azapagic & Perdan 2000). The inclusion of this category gives an indication of a firm’s investment in human capital. Ethics indicators take into consideration preservation of cultural values, as well as company conduct which can be benchmarked against international standards (Azapagic & Perdan 2000). Social indicators under consideration also include welfare aspects related to employee satisfaction. Ethical indicators are reported qualitatively whereas welfare indicators are translated into quantitative measures.

Azapagic’s framework for sustainable development indicators in the mining and minerals sector

Azapagic (2004) proposed a sustainability indicator framework for the mining and minerals sector which was based on the GRI indicator framework. The framework is targeted towards large-scale mining and large organisations due to the time and resources required for its implementation. The developed indicators use a life cycle approach, following all activities from ‘cradle to grave’, and consider the whole supply chain and relevant stakeholders. The stages included in the supply chain include processes involved in primary mineral extraction and production of mineral products, production of other final products, use and post-use waste, as well as recovery and reprocessing. The framework includes economic, environmental, social and integrated indicators which combine two or

more aspects of sustainability in order to provide a more holistic assessment as well as reducing the number of criteria that need to be considered (Azapagic 2004). The integrated indicators are combinations of the three pillars of sustainability according to the triple bottom line, i.e. environmental-economic, social-environmental and social-economic. Examples of integrated indicators include eco-efficiency, energy and material intensity of products, total investment in environmental, health and safety as a percentage of profit, and human capital investment as a percentage of profit. Although integrated indicators are included in the framework they are currently in the early stages of development (Azapagic 2004; Petrie et al. 2006). Integrated indicators can be related to the approach utilised by the Wuppertal Institute, whereby the framework includes interlinkage indicators between the different pillars of sustainable development. Integration between pillars has the potential to reduce trade-offs between pillars and promote a more holistic approach to sustainable development (Azapagic 2004; Rosenburg et al. 2006).

Many of the indicator categories proposed by Azapagic (2004) are now represented in the G4 GRI guidelines (GRI 2013b) and/or in the GRI Mining and Metals Sector Disclosure (GRI 2013a). However, the environmental indicator category ‘mineral resources’ contains indicators (explained in Table A-1) that are yet to be adequately addressed under the GRI frameworks. These indicators can be related to the sustainability conditions presented by The Natural Step framework (Robèrt et al. 2002), and are concerned with resource use and management, particularly with regards to resource efficiency.

Table A-1: Environmental indicators under the mineral resource category (Azapagic 2004)

Indicator	Provides information on/measures
Breakdown of the amount of each saleable primary resource extracted	Amounts of primary resources that need to be extracted to obtain mineral products and through that the rate of extraction and depletion of natural resources
Total waste extracted (non-saleable material, including the overburden)	The amount of waste that needs to be moved to obtain mineral products
Total products’ yield as percentage of the amount of saleable products relative to the total amount of material extracted	Resource efficiency with respect to the total amount of material that needs to be extracted to obtain a certain amount of saleable mineral product
Percentage of each resource extracted relative to the total amount of the permitted reserves of that resource	Rate of depletion of the permitted reserves also indicating how long a company can rely on existing (permitted) resources

Labuschagne et al.'s proposed sustainability framework for industry

Labuschagne et al. (2005) proposed a framework to assess sustainability performance of companies in the process industry. The framework consists of a set of criteria that have been developed through engagement with relevant stakeholders within the South African process industry. However, the framework only proposed a set of criteria to be taken into consideration and indicators are yet to be developed.

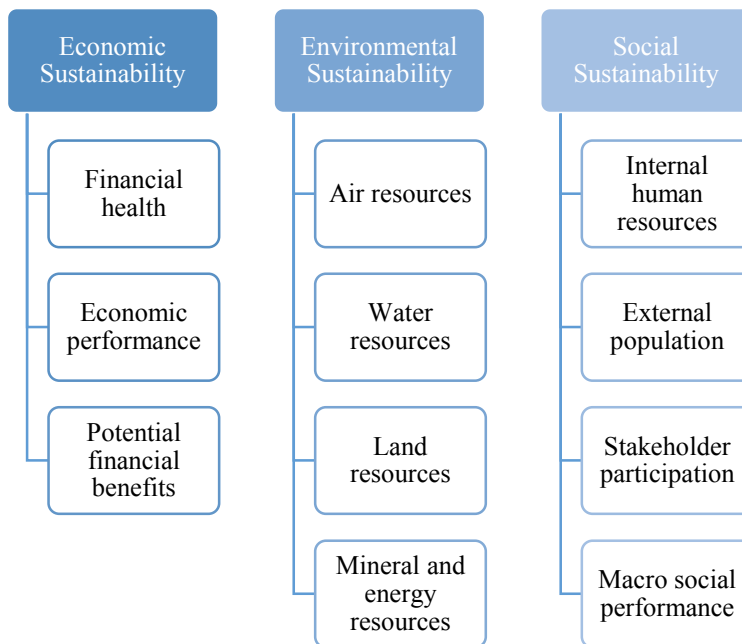


Figure A-4: Labuschagne et al.'s (2005) proposed framework for sustainability performance in industry

The framework also placed more emphasis on the social dimension of sustainability with the bulk of the research being focused on exploring the different criterion that fall within this scope and in 2006, Labuschagne & Brent developed a social sustainability framework specifically for use at operational levels in developing countries. This was based on the premise that current frameworks do not effectively address social sustainability issues on this level. The framework is set apart from other frameworks for social sustainability by the indicators proposed under the category of external population. The proposed indicators can be directly linked to the social issues that are prevalent within local communities such as the availability of housing, water and energy services as well as local population migration (Labuschagne & Brent 2006). The integration of these issues as standalone indicators within the framework makes it easier to assess the social performance of industries in surrounding communities, unlike within other frameworks which place less emphasis on these issues. However, the macro-perspective on social sustainability means that there is little consideration on social impacts experienced by employees. Taking into consideration the numerous health and safety risks faced by employees in the mining and metals sector, as well as the currently very strained labour/management relations, this omission gives the impression that the framework is rather incomplete.

Indicator Development in the Iron and Steel Industry

There is currently no shared and recognised guideline for sustainable development indicators that are tailored specifically for the iron and steel sector (Arena & Azzone 2010; Strezov et al. 2013). A key challenge faced by the industry is the development of processes that promote sustainability (Fruehan 2009). Fruehan (2009) defines five sustainable steelmaking goals:

- i. Conservation of natural resources (e.g. ore and coal)
- ii. Reduction of greenhouse gas emissions (e.g. carbon dioxide)
- iii. Reduction of volatile emissions
- iv. Reduction of materials to landfill
- v. Reduction of hazardous waste

In their development of a composite sustainability performance index for steel industry Singh et al. (2007) provide a comprehensive approach to developing a methodology for sustainability assessment of steel companies. The methodology organises indicators into the three pillars: economic, environmental and social, as well as organisational governance (e.g. research and development and human resource management) and technical aspects (e.g. defects and labour productivity) (Singh et al. 2007). Quantitative indicators were utilised for environmental and economic indicators whereas qualitative indicators were employed for most societal and organizational governance indicators. Stakeholder engagement was a key aspect of indicator selection, with stakeholders being used to identify sustainability issues within the sector and the final set was based on ratings provided by a panel of experts.

Arena & Azzone (2010) propose an approach that allows selection of an indicator set taking into account relevance of different sustainability issues in different contexts. The approach is based on the GRI framework and follows a four stage process to the development of an indicator set:

- a) Competitive analysis which identifies key sustainability issues
- b) Process and technology analysis led by third-party technology experts
- c) Preliminary indicator set development based on suggestions by third party experts
- d) Choice of final indicator set through consultation with steel companies to ascertain if proposed indicators can be measured in a reliable and affordable manner

This approach highlights the need for a “fitness-for-purpose” emphasized by Levett (1998). This is supported by the differences observed between the steel industry frameworks developed by Singh et al. (2007) and Arena & Azzone (2010) which were developed within developing and industrialised countries respectively. When applied to the Italian steel industry, many of the social indicators suggested by the GRI framework were deemed to be irrelevant, such as child and forced labour, non-discrimination and freedom of association (Arena & Azzone 2010). However, these are taken into account for the indicator set developed by Singh et al. (2007) which was evaluated for a steel company in India. This illustrates the importance of developing indicator sets specific to the context, and the risks associated with blindly adopting an existing indicator set. This also emphasizes the need for stakeholder engagement in the development of relevant indicator sets but the quality of the results will be highly influenced by the quality of actors involved (Arena & Azzone 2010).

The World Steel Association (WSA) (2013) provides a list of eight sustainability indicators which are categorized according to the triple bottom line. They include environmental sustainability (greenhouse gas emissions, energy intensity, material efficiency and environmental management systems), economic sustainability (investment in new products and processes and economic value distributed) and social sustainability (lost time injury frequency rate and employee training). The indicators aim to compare global historical trends of indicator trends based on average figures derived from members of the WSA (WSA 2013).

Appendix B MCDA Techniques

There are a growing number of MCDA techniques which can be used in the evaluation and comparison of different alternatives. Several characterisations of multiple criteria evaluation methods have been made in a bid to provide guidance on method selection according to decision situations. Based on distinctions made by Stewart (1992) and Guitouni & Martel (1998) the procedures may be classified according to five categories: elementary, single index, outranking, mixed and interactive (see Basson 2004). These procedures can be further classified according to characteristics of the decision situation, including the type of criteria (ordinal, cardinal or mixed), degree of compensation, preference elicitation mode and moment (prior, progressive or post-optimisation) as well as the aggregation procedure (Guitouni & Martel 1998; Azapagic & Perdan 2005b). MCDA techniques can be used to identify a single most preferred option, to provide a short-list of options for further analysis or to distinguish between acceptable and unacceptable option (Belton & Stewart 2002).

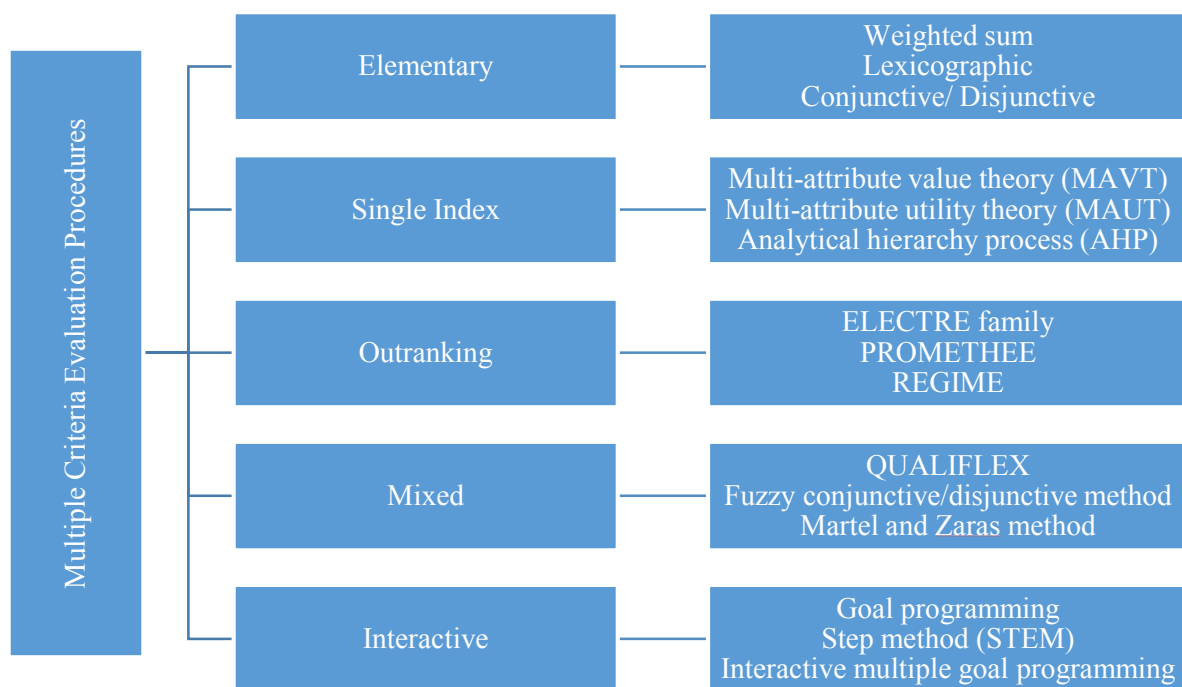


Figure B-1: Classification of multiple criteria evaluation procedures (Basson 2004)

Elementary methods are non-compensatory in nature, and do not necessarily allow comprehensive consideration of all criteria in the evaluation of alternative (Basson 2004; Azapagic & Perdan 2005b). Therefore, this does not allow a full representation of stakeholder perspectives. Without the consideration of criteria it makes it possible for important issues to be overlooked as well as trade-offs occurring implicitly. Without the inclusion of all criteria in alternative evaluation, the inclusion of elementary methods under the umbrella of MCDA is debateable (Basson 2004).

Methods of prior articulation of preferences (single index, outranking and mixed) are recommended in contexts where transparency is key and full justification and rationale for decisions is required (Stewart 1992; Basson 2004). These methods would also be more practical in cases where extensive interaction between stakeholders and analysts, such as that required in interactive methods, is not possible due to limited time and funds. However, mixed methods introduce a level of complexity into the analysis

making them inaccessible to non-specialists. Interactive methods, consisting of goal programming and reference point methods, are utilised in situations when decision makers find it difficult to express trade-offs or weights (Belton & Stewart 2002). Instead they describe scenarios which they deem satisfactory which are expressed in terms of goals or aspirations of each criterion. This approach is recommended for use in the early stages of problem analysis as a screening tool to generate a shortlist of alternatives (Belton & Stewart 2002; Azapagic & Perdan 2005b). It can also be related to the design problematique, whereby new alternatives are identified based on the goals and aspirations of decision makers (Belton & Stewart 2002).

The intention of single index methods (also known as value- and utility- based approaches) is to construct a means of associating a real number to the performance of each alternative, in order to produce a preference order of alternatives that is consistent with decision makers' preferences (Belton & Stewart 2002). This is done via aggregation across different criteria, with some form of weighting being applied to reflect their relative performance. The weighting is representative of the inter-criteria trade-offs a decision maker is willing to make. As such, these approaches are based on partial or total compensation and require explicit articulation of preferences. Single index and outranking approaches are commonly recommended for decision making in strategic contexts (Basson 2004; Azapagic & Perdan 2005b). In particular, Azapagic & Perdan (2005) recommend the use of MAUT for decision making in the context of sustainable development, which is often characterized by uncertain conditions and facts, due to its ability to deal with uncertainty.

The outranking approach arose out of an attempt to avoid the assumptions that there is always scope for some form of compensation to occur, and that there exists a 'best' alternative that is representative of the decision makers preferences (Stewart 1992). It has been promoted for its non-compensatory approach and the ease with which uncertainties can be taken into consideration within the evaluation (Azapagic & Perdan 2005b). Similarly to elementary methods, outranking approaches also utilise thresholds to ensure that bad performance in one criterion cannot be compensated by good performance in another. Pairwise comparison of criterion is conducted motivated by the fact that preferences and values are often formed within a particular decision making context (Belton & Stewart 2002). The approach has been criticised for lacking theoretical backing particularly in terms of what constitutes outranking and the way threshold values are set (Stewart 1992; Azapagic & Perdan 2005b). Whilst the outranking approach can help focus attention on critical issues it is better suited for situations where there is a relatively small number of alternatives under consideration (Stewart 1992).

Preference Elicitation Techniques

The SMART, SWING and trade-off methods are more advanced preference elicitation techniques which are commonly used in MCDA (Belton & Stewart 2002; Azapagic & Perdan 2005b; Riabacke et al. 2012). For the SMART method, the least important criterion is assigned 10 points and the remaining criteria rated relative to the least important one. However, the lack of an upper limit decreases the reproducibility of results if the same test is conducted with the same participant (Riabacke et al. 2012). The SWING weighting method relies on determining the 'swing' between criteria (Belton & Stewart 2002). This is done by asking the decision-maker to consider a scenario with the worst consequences for all criteria and identify which criteria is most important to improve to its best performance. the most important criterion is assigned 100 points and the procedure repeated with the rest of the criteria, which are rated relative to the most important one (Riabacke et al. 2012). Trade-off methods involve pair-wise

comparison of criteria where two hypothetical alternatives are presented to the decision-maker (Riabacke et al. 2012). Although many techniques may be viewed as minor variants of another, the small differences can have important impacts on decision-making (Bottomley & Doyle 2001).

Appendix C Interview Protocol

Questionnaire

1. What is your current view on the scrap metal recycling industry?
 - Both on a macro and micro scale
2. What do you view as the biggest challenges/threats to the industry?
3. What do you view as the biggest opportunities?
4. How do you view government's role in the scrap metal industry?
5. How do you view the interaction between the various stakeholders in the industry?
6. What is your perception for the future of the steel scrap metal industry?

7. As part of my study I would like to conduct a short exercise to ascertain the relative influence different issues have on decision making. The short exercise will require you to rank a set of sustainability issues and assign scores to them according to their importance. As such the exercise has been split into three steps. Please may you fill in the results of each step in Table C-1? A short example is available on the final page.
 - a) Based on background research a list of sustainability issues has been compiled. Which of these issues do you consider to be relevant when it comes to making decisions surrounding the fate of scrap steel? If you feel that a pertinent issue has been overlooked please feel free to make additions to the list. Please indicated relevance with either "Y" for yes, or "N" for no.
 - b) Please may you rank the issues you consider relevant in order of their relative importance when it comes to deciding whether or not to increase local beneficiation of scrap metal? The purpose of this is to determine which issues you consider to be most important when it comes to the debate surrounding scrap metal consumption vs exportation.
 - c) In order to ascertain the relative influence these issues have on decision-making it is necessary to score them. Starting with a score of 100 points for the most important issue, please assign scores to the rest of the issues relative to the most important issue.

Table C-1: Preference elicitation exercise

Issue	Relevance	Rank	Score
Contribution to GDP			
Contribution to balance of payments			
Production costs			
Profitability			
Market risk			
Value addition			
Water management			
Energy			
Air pollution and climate change			
Waste production			
Job creation			
Skills availability			
Access to raw materials			

Exercise example

Issue	Relevance	Rank	Score
Contribution to GDP	N		
Contribution to balance of payments	N		
Production costs	Y	2	95
Profitability	N		
Market risk	Y	4	63
Value addition	N		
Water management	N		
Energy	Y	3	70
Air pollution and climate change	N		
Waste production	N		
Job creation	N		
Skills availability	Y	5	40
Access to raw materials	Y	1	100

Informed Consent Form

Sustainability performance analysis and decision-making for minerals beneficiation: A South African iron and steel case study

I, the undersigned, confirm that (please tick box as appropriate):

1.	I have understood the objectives of the project, as explained by the researcher.	<input type="checkbox"/>
2.	I have been given the opportunity to ask questions about the project and my participation.	<input type="checkbox"/>
3.	I voluntarily agree to participate in the project.	<input type="checkbox"/>
4.	The procedures regarding confidentiality have been clearly explained to me.	<input type="checkbox"/>
5.	I agree to the audio recording of this interview.	<input type="checkbox"/>
6.	I understand that other researchers will have access to this data only if they agree to preserve the confidentiality of the data and if they agree to the terms I have specified in this form.	<input type="checkbox"/>

Participant:

Name of Participant

Signature

Date

Researcher:

Name of Researcher

Signature

Date

Appendix D Ethics Clearance

EBE Faculty: Assessment of Ethics in Research Projects (Rev2)

Any person planning to undertake research in the Faculty of Engineering and the Built Environment at the University of Cape Town is required to complete this form before collecting or analysing data. When completed it should be submitted to the supervisor (where applicable) and from there to the Head of Department. If any of the questions below have been answered YES, and the applicant is NOT a fourth year student, the Head should forward this form for approval by the Faculty EIR committee; submit to Ms Zulpha Geyer (Zulpha.Geyer@uct.ac.za; Chem Eng Building, Ph 021 650 4791).
NB: A copy of this signed form must be included with the thesis/dissertation/report when it is submitted for examination

This form must only be completed once the most recent revision EBE EIR Handbook has been read.

Name of Principal Researcher/Student: Takunda Yeukai Chitaka Department: Chemical Engineering

Preferred email address of the applicant: chttak002@myuct.ac.za

If a Student: Degree: MPhil specialising in sustainable mineral resource development
 Supervisor: Prof Harro von Blottnitz

If a Research Contract indicate source of funding/sponsorship:

Research Project Title: Sustainability performance analysis and decision-making for minerals beneficiation: a South African iron and steel case study

Overview of ethics issues in your research project:


Question 1: Is there a possibility that your research could cause harm to a third party (i.e. a person not involved in your project)?	YES	NO ✓
Question 2: Is your research making use of human subjects as sources of data? If your answer is YES, please complete Addendum 2.	YES ✓	NO
Question 3: Does your research involve the participation of or provision of services to communities? If your answer is YES, please complete Addendum 3.	YES	NO ✓
Question 4: If your research is sponsored, is there any potential for conflicts of interest? If your answer is YES, please complete Addendum 4.	YES	NO ✓

If you have answered YES to any of the above questions, please append a copy of your research proposal, as well as any interview schedules or questionnaires (Addendum 1) and please complete further addenda as appropriate. Ensure that you refer to the EIR Handbook to assist you in completing the documentation requirements for this form.

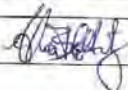

I hereby undertake to carry out my research in such a way that

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

Signed by:

	Full name and signature	Date
Principal Researcher/Student:	Takunda Yeukai Chitaka 	19 March 2015

This application is approved by:

Supervisor (if applicable):	Harro von Blottnitz 	20 March 2015
HOD (or delegated nominee): Final authority for all assessments with NO to all questions and for all undergraduate research.		
Chair: Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	G. S. Hule 	13/05/2015

ADDENDUM 2: To be completed if you answered YES to Question 2:

It is assumed that you have read the UCT Code for Research involving Human Subjects (available at <http://web.uct.ac.za/depts/educate/download/uctcodeforresearchinvolvinghumansubjects.pdf>) in order to be able to answer the questions in this addendum.

2.1 Does the research discriminate against participation by individuals, or differentiate between participants, on the grounds of gender, race or ethnic group, age range, religion, income, handicap, illness or any similar classification?	YES	NO✓
2.2 Does the research require the participation of socially or physically vulnerable people (children, aged, disabled, etc) or legally restricted groups?	YES	NO✓
2.3 Will you not be able to secure the informed consent of all participants in the research? (In the case of children, will you not be able to obtain the consent of their guardians or parents?)	YES	NO✓
2.4 Will any confidential data be collected or will identifiable records of individuals be kept?	YES ✓	NO
2.5 In reporting on this research is there any possibility that you will not be able to keep the identities of the individuals involved anonymous?	YES ✓	NO
2.6 Are there any foreseeable risks of physical, psychological or social harm to participants that might occur in the course of the research?	YES	NO✓
2.7 Does the research include making payments or giving gifts to any participants?	YES	NO✓

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

The completed questionnaires and interviews will need to be linked with the name of the information provider to enable interpretation. In the dissertation, however, this evidence can be presented in anonymised form. The supervisor will have access to the raw data. The researcher and supervisor will take care to treat this information as confidential.

Whilst every attempt will be made to keep identities of stakeholders anonymous in cases where this might not be possible (e.g. should the interviewee be a representative of an easily identifiable company), this will be made known to the interviewee. The researcher will offer to make a draft of the findings available to the interviewee for comment before inclusion in a publication, with the condition that they will only be published with their approval. Should this arrangement not be agreeable to the participant the interview will not proceed.

ADDENDUM 3: To be completed if you answered YES to Question 3:

3.1 Is the community expected to make decisions for, during or based on the research?	YES	NO
3.2 At the end of the research will any economic or social process be terminated or left unsupported, or equipment or facilities used in the research be recovered from the participants or community?	YES	NO
3.3 Will any service be provided at a level below the generally accepted standards?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

ADDENDUM 4: To be completed if you answered YES to Question 4

4.1 Is there any existing or potential conflict of interest between a research sponsor, academic supervisor, other researchers or participants?	YES	NO
4.2 Will information that reveals the identity of participants be supplied to a research sponsor, other than with the permission of the individuals?	YES	NO
4.3 Does the proposed research potentially conflict with the research of any other individual or group within the University?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

Appendix E Interview Summaries

The views and information contained in the following summaries are exclusively those of the participants. Details of participants' operations have been omitted from the summaries to maintain confidentiality.

Participant 1: Metal recycler

KwaZulu-Natal Province

Participant 1 was actively engaged in the debate surrounding scrap metal exports for many years. These experiences formed the basis of the opinions expressed.

According to participant 1, scrap metal availability was never an issue until government made it an issue. Currently there are approximately 3 million tonnes of scrap generated of which there is only a domestic demand for 1.5 million tonnes. Consequently, the excess scrap is exported into global markets. The current geographical setup of the manufacturing industry, whereby major consumers are located inland, was also cited as a mitigating factor for the export of scrap by coastal recyclers. This is due to the logistical requirements associated with transportation of scrap inland which would greatly increase the cost of scrap making this option inviable. The foundry industry is currently facing a host of more pertinent issues related to energy, labour and production costs and skills availability. A lack of investment in the industry has also resulted in the current operation of aged and inefficient technologies. In the participant's opinion, the decision to control one aspect of the issues currently faced by foundries and not any others did not make sense.

The scrap recycling industry is a cash based sector which operates on very slim margins (approximately 10%). It is as close to free trade as price is decided between the supplier and buyer. The participant considers the preferential pricing system as infringing on this free trade. The lack of an official pricing system has resulted in the government basing prices on data from countries with different socio-economic landscapes. These prices does not take into consideration the local factors that impact pricing. This results in a pricing system that is very conservative and recyclers end up losing a significant portion of their revenue (20% – 30%). The participant also emphasised the knock on effect that restriction on scrap metal would have on the informal sector. Forcing scrap recyclers to sell their scrap at lower prices would force them to lower their buying price so as to maintain profit margins. This means that informal collectors receive a lower price for the same volume of scrap. This devaluing of scrap also affects manufacturing industries who sell scrap resultant from their processes. They are then forced to sell the steel, which they originally purchased at full price, at a discounted rate. This results in loss of revenue in a sector that the government is trying to grow.

When it comes to stakeholder interactions, the participant felt the need for more constructive dialogue amongst stakeholders. More specifically, between government and industry. The participant made particular reference to previous attempts the metal recycling industry had made to engage the government. For example, the metal recycling industry had engaged extensively with the foundry industry to try and formulate amicable solutions that would remediate the current decline of the latter. This process resulted in the compilation of a report (Conningarth Economists 2013) which was later presented to government. The participant felt that the implementation the policy directive on scrap exports was contrary to the findings of the report which led to a lot of disgruntlement amongst industry

players who participated in the process. According to the participant, the metal recycling industry has attempted to engage the government on multiple occasions but have either been met with resistance or have ultimately felt that their input was not taken into consideration during the decision-making process. In their opinion, “the government only wants to hear opinions that affirm their beliefs.”

Overall, the participant came across as very attune to the plight of the foundry industry and the various sustainability issues being faced by the scrap metal industry as a whole. They took a holistic approach to decision-making and were ultimately driven by the prospect of sustainable growth of the entire industry.

Participant 2: Metal Recycler Western Cape Province

The participant was very welcoming and eager to share his vast knowledge of the metal recycling industry. They came across as having a strong character, and was very candid with their opinions.

The interview began with a general overview of their operations, particularly the factors that influence the decision to export or sell scrap on the domestic market. According to the participant, the maintenance of good relationships between recyclers and consumers plays an integral part in the flow of scrap metal. They spoke to the change in relationship dynamics over the years. In the past, there was a lot of interaction between consumers and suppliers but over the years there has been a lack of communication which has contributed to a breakdown in these relationships. This breakdown has resulted in a lot of tension festering between dealers and consumers.

When it comes to the decision to supply locally the participant stated, “We would love to supply locally, if they would take all our stuff.” The participant currently supplies any high quality grades they recycle to local foundries. Currently relationships exist with consumers whereby they provide orders at export parity pricing which takes into consideration transport and logistical costs. The participant referred to consumers as “price makers” when it comes to reaching sales agreements. Any excess scrap that remains after local consumers have purchased what they require is exported. However, the participant admitted that it is generally easier to export than sell locally as payment terms are better on export.

The participant has been actively engaged with debates surrounding the scrap metal industry at large, particularly in the policy intervention space. They were clearly disgruntled by the current intervention regarding scrap exporting stating emphatically, “Government seems hell bent on destroying industry left, right and centre! I don’t need government to tell me how to interact with companies.” According to the participant, there have been occasions when local consumers have objected export permit applications but neglect to follow through resulting in stock accumulating in the yard. This introduces a lot of risk, insecurity and uncertainty into metal recyclers operations. Consequently, there is a lack of investment in the industry which in turn affects employment and productivity.

When it comes to sustainability issues, the participant found only two to be of relevance; production costs and market risk. The decision to export is by and large determined by demand. Domestically, the market cannot absorb all of the scrap that is generated, and the surplus is exported. The influence of production costs varies according to whether or not the participant is compensated for any additional

processing requirements. However its relative influence was small as the participant is commonly compensated.

Participant 3: Metal Recycler Organisation

Gauteng Province

Throughout the interview the participant placed a lot of emphasis on the relationships that exist in the scrap steel industry. There is reportedly a healthier relationship in the non-ferrous industry in comparison to the ferrous industry where there was no negotiation on price and consumers adopted a “take it or leave it approach”.

The participant felt that the current focus on scrap metal exports as a contributing factor towards the decline of the foundry industry was a case of blame shifting. In their opinion, the foundries have a host of challenges they need to overcome which would not be solved by lowering the costs of scrap metal. They made reference to a lack of investment in new technologies in the industry which meant that current processes that are highly inefficient. This also introduces a constraint in terms of the grades of scrap the foundries can process whilst still maintaining efficiency. The participant also referenced the rising electricity costs coupled with the insecurity introduced by load shedding. In comparison to these issues the scrap industry could be viewed as “an easy target”.

The participant refuted claims that scrap prices were exorbitant on the basis that they were market related. The participant also refuted the allegation that the premium quality scrap is currently being exported whilst only lower grades are being made available on the domestic market. Exports primarily consist of material that cannot be processed locally as domestic consumers are usually willing to pay market related prices for high quality grades. In their opinion the current debate surrounding scrap exports was simply a way for foundries to get cheaper material and decrease their production costs. As stakeholders in the scrap metal industry the participant said, “We all have a common goal – we want to maximise profits!” However, they were against consumers maximising profits at the expense of recyclers which they believed was currently the case.

When it comes to interactions between stakeholders, the participant viewed government as being very reactive to a “plight from a dying industry”. They did not view this as a localised phenomenon, whereby globally inefficient foundries are being overtaken by larger, more competitive and more efficient technologies, and as a result are forced to shut down. In their opinion, government had made scrap export an issue when it was not. The government was also viewed as reacting to the job losses associated with foundries shutting down. Pressure from trade industries threatening strike action in the metal industries should the government not introduce interventions to ensure job security required the government to be “seen to be doing something.” However, the participant agreed that the foundry industry needs help and was willing to be a participant in how that could best be achieved. They recognised the importance of the foundry industry stating, “We do business with them, and if they disappear local beneficiation will decrease even more and we will be forced to export.” With this in mind the participant went on to say, “We all have the same objectives, how we reach them is the grey area.” Meaningful dialogues amongst stakeholders were viewed as crucial to this process. The participant emphasised that, “Government is going to be crucial in whether they are prepared to sit down and have a platform where these issues are going to be discussed.” From their perspective, the current views and input of the metal recyclers was not being taken into consideration despite efforts to

engage with various government departments. They made particular reference to a consultation process that had occurred between the foundries and metal recyclers in an effort to formulate an amicable solution to remediate the current decline of the former. This process resulted in the compilation of a report (Conningarth Economists 2013) which was later presented to government. However, they felt that the results of this report were not taken into consideration when the policy directive was formulated, whereby, the report had advised against any restrictions on exports. As a result there was a lot of disgruntlement on the part of the recyclers.

The current policy directive was viewed as having little or no effect on current operations. On a firm level, the participant currently has historical agreements with consumers which supersede the preferential pricing system. When it comes to exports, they have not found any resistance from consumers in the form of applications to purchase scrap destined for export. However, the participant pointed out that any depression in scrap prices would most likely impact the informal sector engaged in scrap collection most negatively. As recyclers, they operate according to margins. So if the achievable price for scrap drops their buying price for unprocessed scrap would drop according. In essence, the people who would be affected are the new scrap generators and informal collectors of obsolete scrap.

In terms of the current drive to increase local beneficiation of scrap, the participant did not view the majority of issues as relevant to their decision of whether or not to export scrap. However, the participant did note that at the current capacity coupled with constraints regarding suitable grades for processing, the consuming industry would not be capable of consuming all the scrap generated. Essentially, market availability would play a large role in influencing the final destination of scrap metal. In contrast to the consuming industries, production costs were not relevant as all scrap is processed according to international standard regardless of its final destination. In terms of access to scrap for processing, the metal recycling industry are essentially in competition with one another to acquire high value material.

Participant 4: Metal Recycling & Foundry Gauteng Province

The participant preferred a more structured approach to the interview, giving very measured and succinct responses to posed questions.

On a macro-scale, the participant directly related the performance of the scrap metal industry to that of the economy. At times when the economy is performing well, with particular reference to infrastructure development and manufacturing, there is increased scrap generation. As such, the market crash in 2008 resulted in a decline of the scrap metal industry across the board.

According to the participant, the decrease in scrap generation coupled with rising overheads have made it difficult for recyclers to maintain profit margins. In other words, stakeholders are facing the challenge of trying to balance out the same expenses against lower sales. When it comes to the matter of scrap exporting vs local consumption the participant pointed to location as a major determining factor. The majority of consumers are located inland therefore scrap recycled inland is likely to be sold on the local market. However, the costs associated with transporting scrap from the coast makes it too expensive to be viable. As such, scrap recycled on the coast is more likely to be exported.

Although the foundry industry has been declining since 2008, the participant made the decision to invest in a foundry with the introduction of the policy directive regarding scrap exports. The participant viewed the new legislation as “an opportunity to make some money” whilst contributing to local beneficiation. By taking into consideration the preferential pricing system the participant determined that the foundry would be a profitable investment. However, the participant acknowledged that the foundry industry is in dire straits with stakeholders struggling to maintain profitability due to rising production costs including scrap prices, electricity and overheads. Electricity is currently major challenge in the foundry industry. Load shedding leads to more frequent start-ups and shut-downs of furnaces, which consumes more power as more energy is needed to heat up the furnace each time. They placed particular emphasis on rising electricity costs stating, “With the way things are, electricity is the biggest cost. It’s murdering them and us!” Electricity supply was also viewed as an issue from a recycling perspective as it is highly mechanized.

Throughout the interview the participant’s desire to contribute to sustainable socio-economic growth in South Africa was a constant theme. Their dedication to this shone through when they stated, “I would like to contribute as much as possible of all material generated in this country to this country.” In fact, the participant went on to say that they did not like the exportation of scrap. The participant took into consideration government goals and strategies, using them to inform his decision-making process. For example, national development strategies place a lot of emphasis on job creation. As a result the participant took job creation into consideration when making decisions.

When it comes to interactions amongst stakeholders the participant reportedly enjoyed good relations with suppliers, consumers and government. The participant expressed unwavering support for the government and initiatives they embark on, including the policy directive on scrap metal. From their perspective there was no point in trying to resist the government. Instead stakeholders should make the effort to work with government. In a nutshell, “Why fight the government? You’re not going to win!”

Participant 5: Foundry KwaZulu-Natal Province

The participant was very accommodating during the interview process. They engaged actively during the interview, displaying a genuine interest in the study and its ultimate goals and objectives. The interview started off with the participant giving an overview of their operations including a history of the firm.

The bulk of the interview was spent discussing the relationship dynamics that exist within the scrap metal industry. The participant described foundries as very secretive organisations that operate independently of one another. The lack of cohesion in the industry leaves them vulnerable to manipulation by scrap recyclers. Scrap recyclers have the power to leverage one foundry against another through selectively supplying one foundry. This makes it possible for scrap prices to be driven up through the desperation of foundries who are not being supplied with scrap. Essentially, the participant viewed the scrap recyclers as having the power to “ultimately control the foundry industry”. In principle, the participant was not against the export of scrap metal. Instead, they were against the export of grades which were suitable for consumption in the foundry industry. There was a lot of suspicion that high grade material was being exported mixed in with lower grades, and hence were not reported on the

permit application. This effectively made it less available to local consumers as they were not being afforded the option to purchase the scrap.

The participant also spoke of potential motivations for scrap exporting. Foundries have specific specifications for processed scrap which may require the recycler to conduct additional processing increasing production costs and decreasing their profit margin. Furthermore, payment procedures for exported scrap allow the recycler to be paid within a week which is much shorter than payments by local consumers which may take up to 60 days.

When it comes to the decline of the foundry industry, the participant admitted that the “foundries have neglected themselves.” According to the participant, foundries are currently facing development, capital investment, technological and raw material challenges. A lack of capital investment has led to many foundries operating with outdated and inefficient technologies. In order to stay competitive on global and international markets, foundries need to invest in technologies that increase output. Foundries are also facing challenges related to skills availability, particularly when it comes to upskilling people for new technology. The participant reported difficulties in finding structured National Qualification Framework module for foundry related activities and as a result the majority of employees are trained on the job.

There was a great sense of unhappiness and disappointment regarding levels of interaction with government. The participant felt that the government was not proactively trying to engage with industry stakeholders which was integral to sustainable growth of the industry. Although the participant acknowledged that the government had recognised the importance of the foundry industry in growing an economy, they believed the government needs to be more innovative in their legislation development. According to the participant, “In order to be innovative, you’ve got to make sure that the guys on the ground have had their input”. Furthermore the participant believed that only through active engagement with the industry, can the government develop an understanding of the challenges that need to be overcome in order to achieve their objectives. The participant also advocated for an approach that took into consideration perspectives of both the foundries and metal recyclers, ensuring that any decisions were not to the detriment of either party.

Participant 6: Foundry Organisation Gauteng Province

As a representative of a foundry organisation, Participant 6 was interviewed so as to provide an industry wide perspective on the debate surround scrap exportation. The participant began by giving an overview of the overall scrap metal industry, and then delved into more detail on the foundry industry, particularly the operations. The foundry industry requires specially selected material in order to ensure efficiency; it needs to be free of dirt and other deleterious material as well as sized according to the types of furnaces used. In South Africa, the majority of foundries have moved away from cupola melting with mostly electric induction furnaces in operation with a few electric arc furnaces. According to participant 6, the trend is moving towards smaller, more compact, high energy, medium frequency induction furnaces.

The participant attributed the current decline of the foundry industry to a multiplicity of reasons. However, import leakages of components used in the general engineering, automotive and mining industries were cited as a major challenge and possibly the single most important reason. Foundries

which have traditionally been suppliers into those markets have consequently had their order intake reduced. In essence foundries are struggling against these imports which the participant postulated as sign of competitiveness either at foundry level or at the next tier. Challenges pertaining to competitiveness included “rapidly increasing energy costs labour productivity, skills availability, technology adaptation and particularly access and competitiveness in the global market”. The participant also linked the decline to the change in global trade dynamics. Prior to 1994, the economic and political isolation of South Africa meant that industries were relatively insulated due to the trade barriers that existed. After the elections in 1994, in terms of the WTO, South Africa was viewed as capable of trading as a developed nation which allowed a much freer trade to take place. The allowance of free import of a variety of components lead to “severe erosion of the South African manufacturing base”. The decline in the manufacturing industry, e.g. engine assemblies, has decreased demand for castings. This linkage is evident globally whereby the largest producers of castings provide the majority of the world’s manufactured goods.

Energy was also a major concern both in terms of price and availability. Currently, losses incurred during load shedding are so severe that the survival of businesses is threatened. The participant viewed energy as a barrier towards increased capacity in the foundry industry, describing the idea of creating new foundries that are going to be efficient as “a little bit farfetched”. In their opinion, until the energy crisis is sorted out any new businesses were going to have to be either very energy efficient to start with or they will need some form of government subsidy to assist them.

When asked about the current emphasis currently being placed on scrap availability as a major contributor to the decline of the foundry industry, in relation to all the aforementioned issues, participant 6 responded; “I am not saying that availability, price or quality of scrap material dictates whether in fact a particular foundry is more or less competitive against the Chinese or Europeans. It’s a multifactorial thing and the input costs are important.” If the foundries can acquire material that enables optimum efficiency of their melting operations and at lower costs this would increase their competitiveness.

Participant 6 viewed government as having a very important role as it provides policy parameters but is also potentially a large consumer of castings, e.g. in infrastructure development. It also dictates policy with respect to the regulation/control of relationships between material generators and users. However, the participant regarded current interventions by government, in the form of recently implemented policies, as having no effect in the foundry industry. The policies were introduced to try and assist foundries to reduce impact costs and enable them to be more competitive. In particular reference to the price preference intervention implemented by the DTI on scrap metal exports, the participant attributed its failure to two reasons¹⁰. The first regarded the fact that foundries require a particular grade of material and the policy is related to the applications for material exports. The majority of scrap grades listed on export applications cannot be used by foundries so there is no use in foundries applying to purchase the scrap. Secondly, in cases where the material is suitable for foundry use, the foundries and permit applicants have been unable to dialogue regarding sale of that material.

¹⁰ The directive requires scrap merchants to apply for export permits during which domestic consumers can make an application to purchase the advertised scrap at a preferential price.

When asked about his opinion on interactions between different stakeholders the participant responded, “There is not a common approach to ensure foundries are provided with suitable material to enable them to be efficient. Everyone is working according to their own agenda. The government doesn’t seem to listen to the participants in that foundries require a particular type of material in order to be efficient.” There was also some suspicion on the part of the participant regarding the operations of scrap dealers when it came to the application for export permits. The participant suspected that, “material that could be used by foundries is being exported, but as a sweetener to other export consignments”. As such, this material is not listed on the export permit application effectively making it less available to foundries. The foundries then end up using material which is not suited to their operations compromising on their efficiency. With respect to the organisation’s relationship with government, there is a lot of interaction with multiple departments. The work is largely focused on skills development, training and education and representing the industry on issues concerning the environment, energy, technology improvement and assistance with regards to funding. However, despite the level of interactions the participant emphasised that “the real issue is if there’s an output that is completely coherent and the truth is that there is not.” He put forward the creation of more stringent environmental regulations within which the foundries need to operate as an example of an output that does not take into consideration the capability of the industry to comply. Compliance would require large capital investments on the part of the foundries which would have no returns in terms of profitability, and the foundries simply cannot afford it.

Looking towards the future of the industry the participant’s view is that, “unless there is a significant shift in terms of some of the policies of the government, there is going to be further decline in the number of operators. There will be some consolidation and the focus will be infrastructure development and niche market opportunities.”

Overall, the participant was very willing to engage in the consultation process. They drew on their vast experiences in the foundry industries, providing evidence to form the basis of each opinion they voiced.

Participant 7: Integrated metal recycler and steel

Western Cape Province

The participant engaged openly in the interview process drawing on their vast experience in the industry. They cited a desire to increase dissemination of knowledge about the industry as their primary motivation for participating in the study, with the ultimate goal of promoting a greater understanding of the scrap metal recycling industry.

According to the participant, steel mills are currently facing the challenge of supplying a market that is not only very small but is over supplied at the moment. Steel producers simply cannot compete against cheaper imports flooding in from China, where producers are heavily subsidised. As they cannot sell their product on the local market and cannot export it against the Chinese, steel mills have been forced to reduce capacity. In the absence of subsidies, local producers have to account for production costs associated with raw materials, labour energy, transport, and legislative requirements of which the Chinese are not subject to the same conditions. In their opinion, the situation is so dire “it is better for us to take scrap and export it than to try and convert it locally into a product”. In contrast to steel products there is a secure market for scrap metal. The participant compared the promotion of increased

local production by government, without the assurance of a secure market, as akin to “putting the cart before the horse”.

Whilst the participant was in support of beneficiation as a concept they were not in favour of current government strategies to achieve it. In their view, “it doesn’t seem there is a logical thought process behind government decisions.” The participant referred to the policy intervention regarding scrap exports as a “blunt axe designed to destroy the economy”. In their opinion the policy is anti-competitive and against international trade agreements. The policy is also viewed as punishing one industry in favour of another. The knock-on effects of the policy effectively end up disadvantaging the approximately 450 000 informal collectors involved in the metal recycling industry. If the recycler is forced to sell the product at a lower price, they would need to purchase the recovered material at a lower price to maintain profit margins. This not only affects the collectors who’s scrap has essentially decreased in value but generators of new scrap (e.g. motor car manufacturers) who paid full value for their steel and would now be forced to sell it at a lower price. The policy also has the unintended effect of giving consumers the selective ability to target businesses. They can essentially keep objecting to export applications of particular dealers giving an advantage to other dealers allowing their permits to be processed without objection. This could lead to collusion in the industry, allowing consumers to favour their friends. The current policy also does not place an onus of responsibility on beneficiaries to do anything with the difference they accrue from the preferential pricing system. They are not required to create jobs, export or decrease price of products that form inputs to downstream industries and can essentially “pocket the difference.” Instead the participant advocated for an approach that does not openly disadvantage one industry over another. For example, incentivising the foundry industry to increase capacity by offering a rebate for every extra tonne produced.

The participant felt that the policy has introduced a lot of uncertainty and unpredictability in the recycling business. Previously, scrap recyclers would make purchase agreements with customers prior to purchasing and processing a source of scrap e.g. a mine that needs to be demolished or a decommissioned aircraft. The permit application requires the scrap to be in the yard, ready for inspection, following which the process can take up to 15 days. During that time, the exchange rate has changed as well as the price of metal and the recycler may not necessarily obtain the same value as they could have had the deal been concluded prior to processing. This uncertainty has increased the risk associated with metal recycling as the industry is now more vulnerable to fluctuations on international markets due to the imposed waiting periods.

Participant 8: Steel Mill KwaZulu-Natal Province

The participant began the interview by giving an overall view of the firm’s perspective on the issue of scrap exporting. They were in support of exporting scrap as it is an internationally tradeable commodity. The participant was openly against current interventions by government to try and increase local consumption as they believe that supply and demand forces should be at play instead of trying to distort market forces. The participant also held the opinion that the intervention would not achieve government’s ultimate goal of promoting downstream industries e.g. the automotive industries. This was due to the fact that the majority of scrap consumed in steel mills is used in the manufacture of

construction products, whereby steel mills that provide inputs into manufacturing industries produce steel primarily from iron ore.

According to the participant, there are a host of issues that need to be addressed before local scrap consumption can be increased. The most important issue was electricity. The current shortage serves as a deterrent for potential investors, as there is no security of supply. Secondly, there is very weak demand in SA therefore there would need to be government support in terms of trade barriers particularly to address the cheap imports from China. At current production costs, it would not be viable to try and export the capacity at international price parity. The steel industry is simply not competitive internationally therefore a secure domestic market is integral to the drive to increase consumption and in turn production. In their opinion, “productivity in this country is too low, cost of capital is too expensive and economies of scale are not achievable.”

When it comes to the nature of interactions between stakeholders, the participant did not believe that a disconnect exists between government and industry. They believed that “there is a spirit of corporation and a drive to reach consensus in the steel industry,” and with a lot of effort a more cordial and corporative relationship will form. Whilst the participant understood government’s motivation for trying to keep scrap in the country in their opinion the current intervention “just doesn’t work”. The failure was attributed to the ability of scrap metal recyclers to circumvent the regulation, coupled in part with insufficient control measures in place to regulate them.

In terms of the future of the industry, the participant’s firm is primarily reliant on iron ore for steel production and therefore did not view an increase of scrap consumption on their side. Should they start decreasing their ore consumption in favour of scrap, the iron ore would likely be exported which is contrary to the current national drive to increase local beneficiation. From their view, “the scrap available should be at market related prices and the scrap recycler should be at liberty to export.” Although steel prices are driven by scrap to a certain extent, the participant did not see why government should put a control on one resource that goes into steel and not the others.

Participant 9: Institutional (finance)

Gauteng Province

Due to logistical constraints, a face-to-face interview was not conducted with participant 9. Instead, correspondence was done electronically whereby the participant was emailed a copy of the questionnaire.

The participant’s responses were short and measured. Whilst acknowledging the relevance of a multiplicity of sustainability issues in the scrap metal industry the participant held the opinion that the export of scrap – particularly the bypassing of legislation by scrap merchants – as the biggest threat to the industry. However, the emphasis was on the availability of industry quality scrap which contains the right mix of heavy scrap that is contaminated with other elements such as copper. Utilising light scrap would require the furnace to be opened more frequently so as to achieve the desired volume, releasing heat and increasing energy costs significantly. Participant 9 claimed that “good scrap” is currently being moved to the coast for export before it is offered to industry. Once at the coast, the logistical costs are so high that the scrap is too expensive to be viably used inland where the large consumers are located.

Participant 10: Institutional (trade and industry)

Gauteng Province

Due to logistical constraints it was not possible to conduct a face-to-face interview with participant 10. Instead correspondence was conducted both electronically and telephonically.

The participant began by giving an overview of the scrap metal recycling industry, including their understanding of the pricing system and the motivating factors for scrap exporting. Currently the scrap recycler has the option to sell to whoever is willing to pay more for the commodity in the absence of a pricing regulatory system. In their opinion, under this setup the market is likely to be distorted. According to the participant, prices in South Africa are “mainly dictated by off-shore buyers who have deep pockets and are willing to source the commodity at any cost.” This has led to the merchants developing a preference for the export market rather than locally where the buyers have less buying power and constrained by other factors. The participant further alleged that the off-shore buyers, through the provision of government subsidies, are able to pay premium prices for input materials.

The participant clearly had a low opinion of scrap recycler, referring to them as “unscrupulous in their dealings”. This opinion was based on past allegations of uncompetitive behaviour in the industry for which the transgressors were found guilty and fined. The participant also did not view scrap recyclers as being supportive of the current drive to increase local beneficiation stating, “The interest of government is to ensure adequate competitive supply into the local industry for value addition which may not be in the interest of the dealers. They are not in the space of industrial development and sell to the highest bidder.” Essentially, the government would want some changes to occur in the supply chain to ensure that scrap recyclers prefer local markets to exports. However, the participant viewed consumers and government as being on the same side “when it comes to improving access to scrap metal”.

When it comes to sustainability issues the industry may currently be facing, the participant highlighted that the way in which they are approached as highly dependent on which perspective you’re looking at them from. Energy consumption was considered highly relevant as the industry is highly energy intensive. The participant also acknowledged that as an input, energy costs will invariably impact profitability. However, they also pointed out that on a global scale energy costs were comparative and electricity prices have “gone up steeply in trying to be in line with global pricing”. In his opinion, due to the relatively low prices that consumers have enjoyed in the past they “have not taken to heart issues of energy efficiency and investing in energy efficient technologies and now they have to catch up.” Interestingly, the participant did not consider market risk as a relevant issue as the government was currently trying to make the industry competitive through their interventions. By decreasing the cost of raw materials there would be decreased production costs, increased profitability and ultimately the industry would become more competitive and the market would be “taken care of.” Increased profitability would also in turn lead to increased value addition. Increased competitiveness would also lead to increased exports and in turn contribution to balance of payments. The participant was not of the opinion that government subsidies for production should be implemented, as is currently the case in countries such as China. Instead, the government was providing support for the long term increased competitiveness of the industry through various interventions. He cited current government investments

in skills development programmes in order to address the skills shortages being faced by the metal and engineering sectors.

Unsurprisingly, access to raw materials was considered to be the most important challenge the industry is currently facing. In order to address the issue there would need to be a change in the current regulatory setup. The participant viewed implementation of high export tariffs or potentially a ban on all scrap exports as possible avenues of recourse, citing that some countries had implemented such interventions. In their opinion a similar approach would lead to pricing that is exclusively domestic, as the high export tariffs would no longer make it viable to export and the local market becomes the preferred market. This would effectively delink the local market from international prices resulting in depressed local prices in the long term. The depressed prices would then make South Africa an attractive metal consuming industry to invest in leading to further development of the downstream manufacturing industries.

Overall the participant was very open and willing to engage in a frank discussion of the scrap metal industry. Throughout all the interactions he was very accommodating and participated with unwavering levels of enthusiasm.

Appendix F Preference Elicitation

Table F-1: Ranking of sustainability issues by participants

Sustainability Issues	Participants										
	1	2	3	4a	4b	5	6	7	8	9	10
Access to raw materials	-	-	1	3	3	2	9	3	8	1	1
Contribution to GDP	6	-	-	8	9	-	12	-	-	13	5
Contribution to balance of payments	5	-	-	11	13	-	10	-	-	12	6
Production costs	4	2	-	2	6	2	2	2	2	2	1
Profitability	3	-	-	1	1	1	3	1	1	10	1
Value addition	7	-	-	6	10	5	6	6	-	5	7
Market risk	1	1	2	9	11	9	1	6	2	4	-
Energy	2	-	-	7	5	5	6	5	4	3	8
Water management	-	-	-	12	12	5	-	9	5	11	-
Air pollution	9	-	-	13	8	9	8	9	5	6	-
Waste production	10	-	-	10	7	9	11	9	5	7	-
Job creation	8	-	3	4	4	8	3	8	-	8	1
Skills availability	-	-	-	5	1	4	5	3	9	9	9

Table F-2: Scoring of sustainability issues by participants

Sustainability Issues	Participants										
	1	2	3	4a	4b	5	6	7	8	9	10
Access to raw materials	-	-	100	90	90	99	40	94	35	100	100
Contribution to GDP	40	-	-	55	55	-	5	-	-	10	95
Contribution to balance of payments	50	-	-	18	20	-	15	-	-	20	94
Production costs	60	10	-	95	65	99	95	95	95	98	100
Profitability	70	-	-	100	100	100	90	100	100	29	100
Value addition	30	-	-	65	50	90	75	92	-	49	80
Market risk	100	100	70	45	45	75	100	92	95	50	-
Energy	80	-	-	60	70	90	75	93	90	97	80
Water management	-	-	-	15	30	90	-	50	50	28	-
Air pollution and climate change	10	-	-	10	60	75	60	50	50	48	-
Waste production	5	-	-	20	62	75	10	50	50	47	-
Job creation	20	-	60	80	80	80	90	85	-	46	100
Skills availability	-	-	-	70	100	95	80	94	10	30	65

Table F-3: Relative influence of sustainability issues on stakeholders

Sustainability Issues	Participants										
	1	2	3	4a	4b	5	6	7	8	9	10
Contribution to GDP	0.086	-	-	0.076	0.067	-	0.007	-	-	0.015	0.117
Contribution to balance of payments	0.108	-	-	0.025	0.024	-	0.020	-	-	0.031	0.115
Production costs	0.129	0.091	-	0.131	0.079	0.102	0.129	0.106	0.165	0.150	0.123
Profitability	0.151	-	-	0.138	0.121	0.103	0.122	0.112	0.174	0.044	0.123
Market risk	0.215	0.909	0.304	0.062	0.054	0.077	0.136	0.103	0.165	0.077	-
Value addition	0.065	-	-	0.090	0.060	0.093	0.102	0.103	-	0.075	0.098
Water management	-	-	-	0.021	0.036	0.093	-	0.056	0.087	0.043	-
Energy	0.172	-	-	0.083	0.085	0.093	0.102	0.104	0.157	0.149	0.098
Air pollution	0.022	-	-	0.014	0.073	0.077	0.082	0.056	0.087	0.074	-
Waste production	0.011	-	-	0.028	0.075	0.077	0.014	0.056	0.087	0.072	-
Job creation	0.043	-	0.261	0.111	0.097	0.083	0.122	0.095	-	0.071	0.123
Skills availability	-	-	-	0.097	0.121	0.098	0.109	0.105	0.017	0.046	0.080
Access to raw materials	-	-	0.435	0.124	0.109	0.102	0.054	0.105	0.061	0.153	0.123

Appendix G Alternative Process Flowsheets

Steel Production Routes

In the production of primary steel, which utilises iron ore as a primary raw material, the iron ore is initially converted into various forms of iron, including pig iron, liquid iron and sponge iron, followed by refining into steel products. The smelting of iron ore into pig iron via the blast furnace route is most commonly employed in South Africa, accounting for 54% of all iron produced in 2012 (SAISI 2013c). Direct reduced iron is a popular alternative to the blast furnace making up 25% of iron production in 2012 (SAISI 2013c).

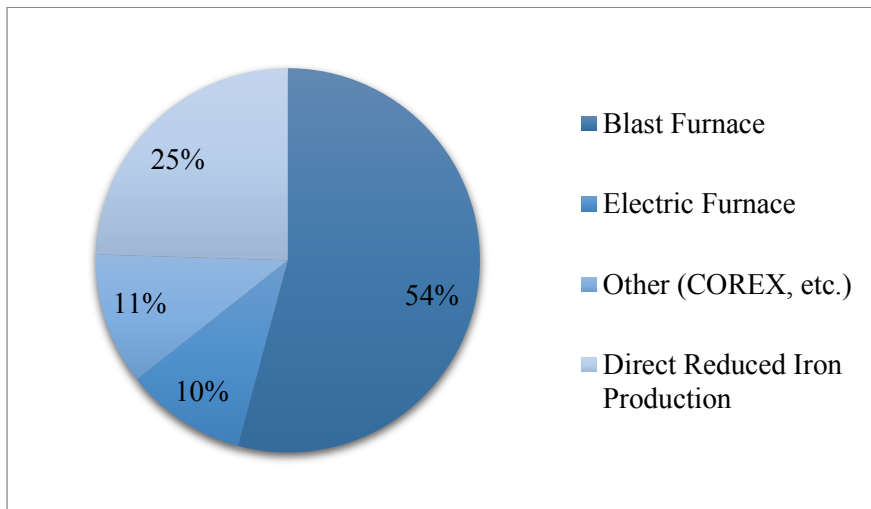


Figure G-1: South African iron production by process in 2012 (SAISI 2013c)

Three different processing routes are used for the production of carbon steel in South Africa: blast furnace/basic oxygen furnace (BF/BOF), electric arc furnace and con-arc furnace. Of the 6.9 million tonnes of crude steel produced in 2012, 44% was via electric processing routes. The BOF predominantly uses oxygen, coal, pig iron (produced from the BF) and scrap steel (up to a maximum content of 30%) as raw materials. The EAF uses electricity to melt recycled scrap steel. Direct-reduced-iron (DRI) may also be used as a feedstock depending on the availability of scrap steel and plant configuration (WSA 2009a).

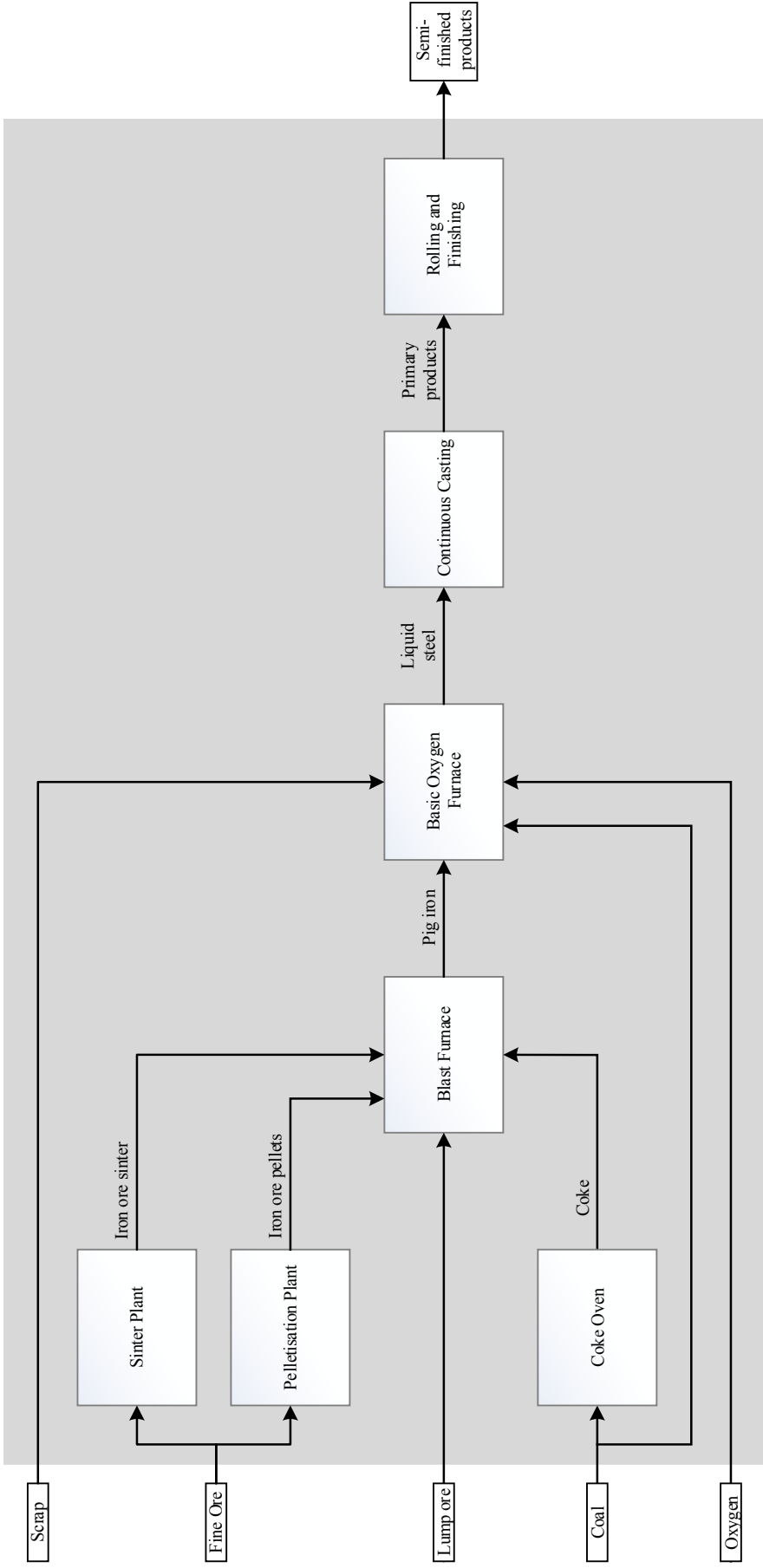


Figure G-2: Primary steel production via the BF/BOF route (WSA 2009a)

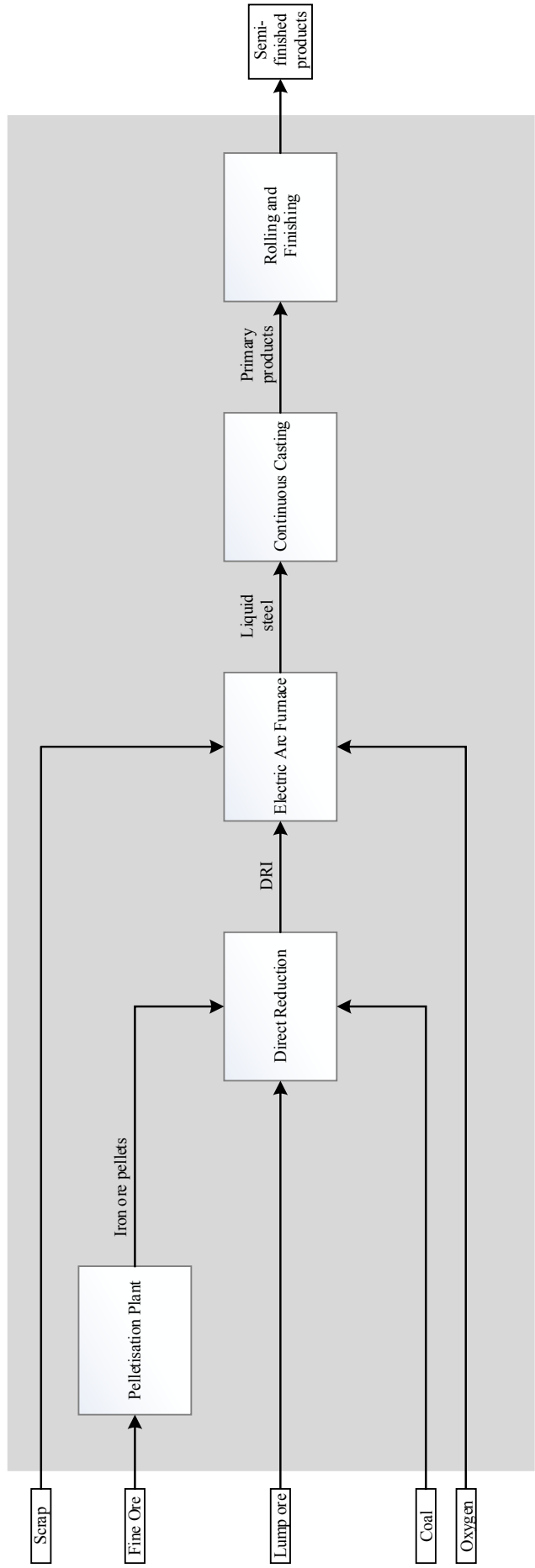


Figure G-3: Primary steel production via the DRI/EAF route (WSA 2009a)

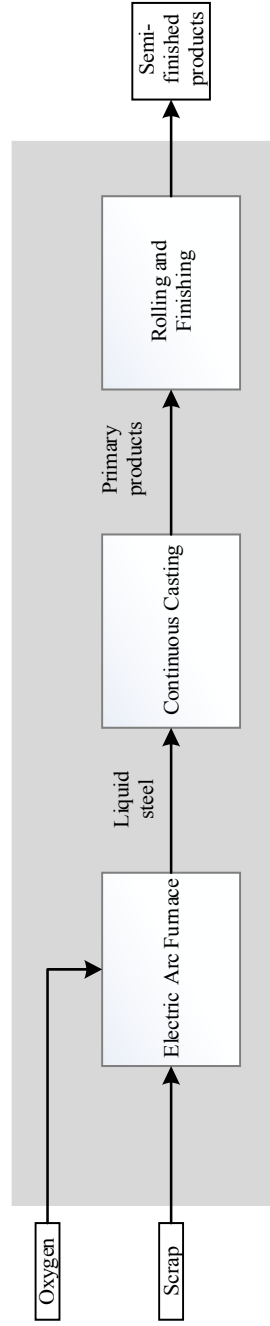


Figure G-4: Secondary steel production via the EAF route (WSA 2009a)

In the case of stainless steel production, alloying elements are added to the EAF. The liquid steel then undergoes argon-oxygen decarburization prior to casting.

The Foundry Process

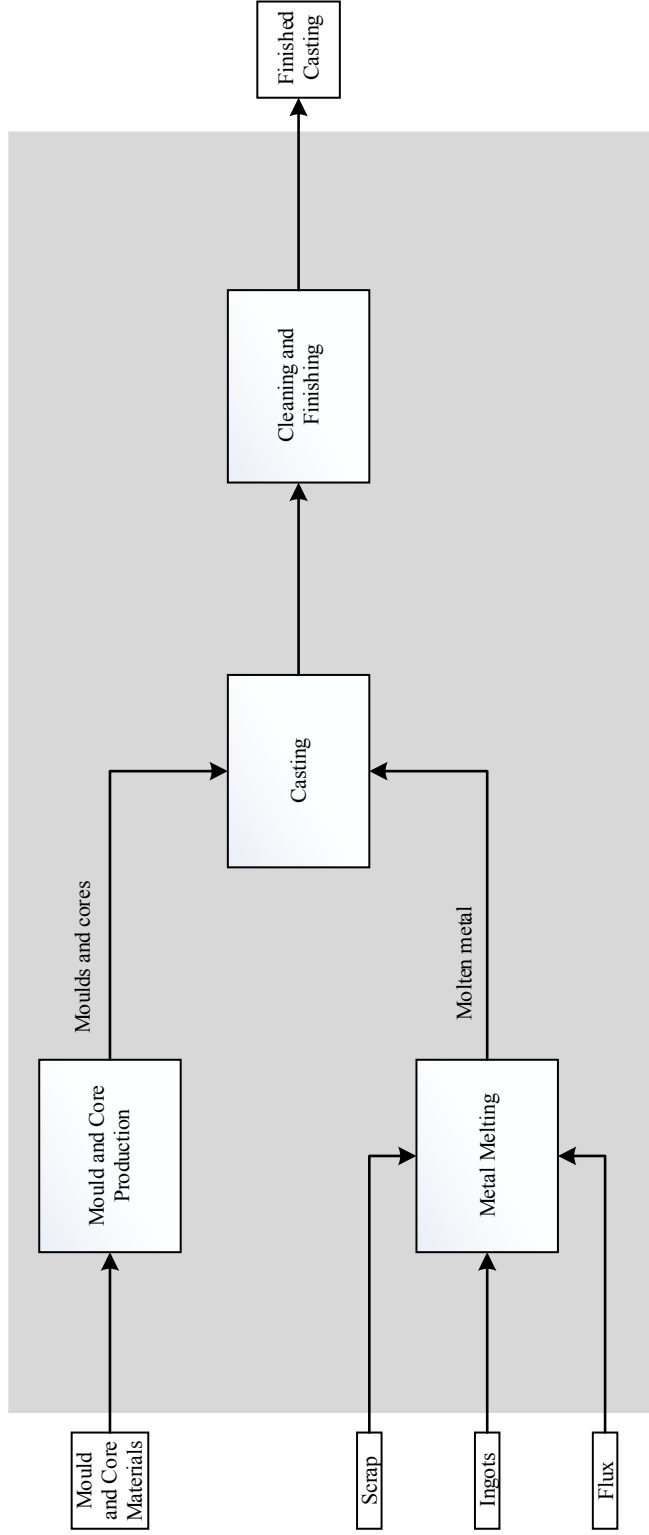


Figure G-5: The foundry process (IPPC 2005)

Appendix H Alternative Evaluation

The alternatives under consideration were evaluated according to their performance in the year 2013. In cases where data was unavailable, estimation were made using relevant data. This Appendix details provides details of any assumptions made, as well sources of information.

Total amount of scrap generated

3 500 000 tonnes (SAISI 2014)

Exporting

For the case of scrap exporting the system boundary was considered to be the port through which the metal passes through before exporting.

Access to raw materials

Amount of product (SAISI 2014): 1 622 885 tonnes

Amount of scrap consumed (SAISI 2014): 1 622 885 tonnes

Direct contribution to GDP

As data was only available for the contribution to GDP for the entire scrap metal recycling industry, this number was scaled down according to the value ratio of ferrous metals.

Total direct contribution to GDP of metal recycling industry (Conningarth Economists 2013): R 3.502 billion

Proportion of metal recycling industry value from ferrous metal (Conningarth Economists 2013): 57.0%

Proportion of ferrous metal exported: 46.4%

Direct contribution to GDP of exported ferrous metals: $3.502 \times 0.570 \times 0.464 = R 0.926$ billion

Contribution to balance of payments

Average market price of ferrous scrap (Steelonthenet 2015): R 3 531 per tonne

Value of exports: $1\,622\,885 \times 4\,693 = R 5.731$ billion

Volume of imports (SAISI 2014): 83 036 tonnes

Value of imports: $83\,036 \times 4\,693 = R 0.293$ billion

Contribution to balance of payments: $5.731 - 0.293 = R 5.44$ billion

Production costs

The scrap does not go any further processing in the port therefore production costs were not considered to be relevant.

Sales value of commodity

Average market price of ferrous scrap (Steelonthenet 2015): R 3 531 per tonne

Gross profit margin

Value from personal communication with stakeholders: 10%

Proportion of product current imported

Criterion not applicable as all of the scrap exported is generated locally.

Environmental performance

As discussed in section 4.5.1, the scrap metal does not undergo any further processing in the port. Therefore, there are negligible environmental emissions associated with scrap exporting.

Socio-economic performance

Scrap exports were considered to have negligible socio-economic impacts. This was based on the volumes of material that go through the ports. In essence, scrap exports present such a small proportion of material that passes through ports, the socio-economic impacts that may be attributed to them are effectively negligible. To illustrate, 1.6 Mt of ferrous scrap were exported in 2013, in comparison to approximately 57 Mt of iron ore exported in the same year. When this is considered in terms of all the imports and exports across sectors, ferrous scrap would represent a small proportion of the total volume.

Steel Mills

Access to raw materials

Amount of product (SAISI 2015e): 7 160 000 tonnes

Proportion of scrap consumed in steel mills (Conningarth Economists 2013): 40.7%

Amount of scrap consumed: $0.407 \times 3\,500\,000 = 1\,420\,000$ tonnes

Direct contribution to GDP

For the steel industry it was only possible to obtain the macro-economic performance of the entire industry in general. This performance did not distinguish between steel products made from scrap or iron ore as primary raw materials. Therefore, the figures were scaled down so as provide an estimate of the potential contribution made by secondary steel products.

Overall industry contribution to GDP (AMSA 2014c; EVRAZ 2014; Scaw 2014): R 29.4 billion

Scaling for proportion of steel produced from scrap: ratio of scrap to steel = $1.42/7.16$

Contribution to GDP: $29.4 \times 1.42/7.16 = R\ 5.83$ billion

Contribution to balance of payments

Value of exports (SAISI 2015b): R 22.1 billion

Value of imports (SAISI 2015d): R 12.4 billion

Overall industry contribution to balance of payments: $22.1 - 12.4 = R\ 9.7$ billion

Contribution scaled for scrap production: $9.7 \times 1.42/7.16 = R\ 1.92$ billion

Production costs

Costs per tonne of molten metal (AMSA 2014b): R 5 929

Sales value of commodity

Average steel selling price (AMSA 2014a): R 7 680

Gross profit margin

Gross profit margin: $(7\,680 - 5\,929) / 5\,929 = 29.6\%$

Proportion of product current imported

Real domestic consumption (SAISI 2015f): 5 690 000 tonnes

Amount of product imported (SAISI 2015f): 1 340 000 tonnes

Proportion of product imported: $1\,340\,000 / 5\,690\,000 = 23.6\%$

Energy

Electricity consumption (AMSA 2008): 1.5 – 4.2 GJ/ t molten metal

Water management

Water consumption(AMSA 2008; AMSA 2014c): 3.1 – 4.07 m³/ t molten metal

Air pollution and climate change

Direct CO₂ emissions (AMSA 2014c): 2.26 tonnes CO₂/ t molten metal

NO_x emissions (EVRAZ 2014): 4.2 kg/ t molten metal

SO_x emissions (AMSA 2014c; EVRAZ 2014): 4.61 – 7.5 kg/ t molten metal

Particulate matter (AMSA 2014c; EVRAZ 2014): 0.08 – 2.8 kg/ t molten metal

Waste production

Total weight of effluents and solid waste produced (AMSA 2014c): 230.7 kg/ t molten metal

Job creation

Number of direct employees (SAISI 2014): 23 000

Employment per 1 000 tonnes of steel: $23\,000 / 7\,160 = 3.2$

Skills availability

According to data from AMSA (2014c) and Scaw (2014), the skills profiles of steel mills can be described of having a majority of skilled workers with some semi-skilled.

Foundries

Access to raw materials

Amount of product (Davies 2015): 343 000 tonnes

Proportion of scrap consumed in foundries (Conningarth Economists 2013): 12.9%

Amount of scrap consumed: $3\,500\,000 \times 0.129 = 453\,000$ tonnes

Direct contribution to GDP

Foundries commonly produce commodities for a variety of metals. As such, data was not available for the specific contribution of the ferrous foundry industry to GDP. Instead a total value for the foundry

industry was used and scaled down according to the proportion of the industry that is composed of ferrous foundries.

Total direct contribution to GDP of foundry industry (Conningarth Economists 2013): R 2.439 billion

Proportion of castings made from ferrous metal (Davies 2015): 91.5%

Ferrous foundry contribution to GDP: $2\,439 \times 0.915 = \text{R } 2.23$ billion

Contribution to balance of payments

Foundries commonly produce commodities for a variety of metals. As such, data was not available for the specific contribution of the ferrous foundry industry to balance of payments. Instead a total value for the annual contribution of the foundry and scrap metal industry was scaled down to determine an estimate for the contribution by the ferrous foundry industry.

2011 estimate of annual contribution to balance of payments (Conningarth Economists 2013): R 10.637 billion

Scrap contribution to balance of payment in 2011 (Conningarth Economists 2013): R 4.118 billion

Proportion scrap contribution: 38.7%

Assuming the same proportion, estimated contribution of the foundry and scrap metal industry: $5.44/0.387 = \text{R } 14.047$ billion

Contribution from foundry industry: $(14.047 - 5.44) \times 0.915 = \text{R } 7.88$ billion

Production costs

Production costs per tonne of cast metal (Mitchell 2013): R 13 999

Sales value of commodity

Sales value per tonne of casting (Mitchell 2013): R 18 120

Gross profit margin

Gross profit margin: $(18\,120 - 13\,999)/13\,999 = 29.4\%$

Proportion of product currently imported

Amount of castings exported (SAISI 2015a): 28 647 tonnes

Amount of castings imported (SAISI 2015c) = 38 205 tonnes

Proportion of products imported = $38\,205 / (343\,240 - 28\,647) = 12.1\%$

Energy

Electricity consumption (El Mohamadi & Mertens 2013; Mitchell 2013): 3.09 – 8.64 GJ/ t molten metal

Air pollution and climate change

Direct CO₂ emissions (IPPC 2005): minor

NO_x emissions (IPPC 2005): minor

SO_x emissions (IPPC 2005): <1 kg/ t molten metal

Particulate matter (Fatta et al. 2004; IPPC 2005; Fore & Mbohwa 2010): 0.04 – 8 kg/ t molten metal

Water management

Water consumption (Fore & Mbohwa 2010): 20 m³/ t molten metal

Waste production

Total weight of effluents and solid waste produced (Fatta et al. 2004; Fore & Mbohwa 2010): 300 - 500 kg/ t molten metal

Job creation

For job creation, the total employment figure for employment in the foundry industry was scaled according to the proportion of ferrous products in the industry.

Number of direct employees (Davies 2015): 9 100

Allocated number of employees in the ferrous foundry industry: $9\ 100 \times 0.915 = 8\ 324$

Employment per 1 000 tonnes of steel: $8\ 324 / 343 = 24.3$

Skills availability

The skills profile of the foundry industry can be described as having a majority of semi-skilled workers, with a mix of skilled and unskilled workers making up the minority (Mitchell 2013).