Comparing sustainable development potential of metal beneficiation industries by using publicly available sustainability information

by

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Abstract

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South Africa has the largest mineral endowment in the world, yet the value it derives from these vast resources remains below potential. This is a direct result of the lack of local beneficiation of these resources (i.e. local value-addition to resources) . This has led the South African government, and governments of other countries facing similar challenges, to pursue increased local beneficiation of its resources. As a result, policy-makers in South Africa and abroad are now faced with the expensive and time consuming process of selecting viable industries that can be developed to increase local beneficiation.

The advent of mainstream corporate sustainability reporting and the subsequent flood of sustainability information into the public domain has now produced an opportunity to make use of this information to effectively select potential industries for which detailed feasibility studies can be done. More specifically, this project aimed to investigate the possibility of developing a framework that makes use of publicly available sustainability information to rapidly, and at a high level, compare potential metal beneficiation industries. This allows prioritisation of feasibility studies on industries showing the most local development potential.

The framework is composed of 18 equally-weighted indicators; 6 for each of the three dimensions of sustainable development. The indicators are constructed from 30 sub-indicators selected from the GRI G4 sustainability reporting guidelines and 10 sub-indicators developed specifically for the framework. The indicators are aggregated using non-compensatory multi-criteria aggregation to produce a single index value for each sustainability dimension, thus allowing comparison of industries in terms of only three index values. Table 3.4 presents a summary of the indicators used in the framework.

In order to test the utility and shortcomings of the framework, platinum beneficiation was used as case study. More specifically, the local production of catalytic converters and platinum jewellery was compared. The catalytic converter industry was found to be superior in the economic and social dimensions with 92 per cent and 81 per cent confidence, respectively. The platinum jewellery industry was found superior in the environmental dimension with 71 per cent confidence. The confidence intervals were calculated from 10 000 iterations in a Monte Carlo simulation conducted to quantify the impact of input uncertainty on the outputs generated by the framework. The superiority of the catalytic converter industry in two of the three dimensions supports the current development policy priorities in South Africa with much focus being placed on further development of the automotive industry.

Based on the results generated by applying the framework to the platinum industry, it was concluded that the framework successfully facilitates the comparison of potential industries. The ease-of-use of the framework, rapid generation of results and hierarchical indicator structure (which allows efficient analysis of the results) were identified as some of the strengths of the framework. Some weaknesses identified included the possibility of subjectivity and embedded effects in input data that may distort the results generated and the dependence of the framework on publicly available information.

It is recommended that further testing of the framework by application to more case study industries be done to ensure the framework indeed captures all necessary effects and adequately compares the industries. Further, broadening the framework to more explicitly include important and unique local factors is cited as a possible improvement that can be investigated in further studies. Finally, based on the successful comparison in this study, it is recommended that the framework be applied to more potential industries as to identify new opportunities and promote their development in South Africa.

Uittreksel

Vergelyking van volhoubare ontwikkelingspotensiaal van metaal waardetoevoegingsnywerhede deur middel van openbare volhoubaarheidsinligting

("Comparing sustainable development potential of metal beneficiation industries by using publicly available sustainability information")

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Suid-Afrika is die mees mineraalryke land in die wêreld, maar die waarde wat plaaslik uit hierdie hulpbronne geput word, is steeds nie optimaal nie. Dít is 'n direkte gevolg van n tekort aan die veredeling van (plaaslike waardetoevoeging tot) hierdie hulpbronne. Die Suid-Afrikaanse regering, en die regerings van ander lande wat voor soortgelyke uitdagings staan, streef nou daarna om plaaslike waardetoevoeging tot hulpbronne te verhoog. As gevolg hiervan is beleidmakers in Suid-Afrika en in die buiteland nou besig met die duur en tydrowende proses om te besluit op lewensvatbare nywerhede wat plaaslik ontwikkel kan word om waardetoevoeging te verhoog.

Die toenemende gebruik onder korporasies om jaarlikse volhoubaarheidsverslae te publiseer, het 'n invloei van volhoubaarheidsinligting in die openbare sfeer tot gevolg gehad. Dit het dit moontlik gemaak om hierdie inligting aan te wend om meer doeltreffende keuses te maak oor nywerhede waarvan die lewensvatbaarheid moontlik verder ondersoek kan word. Hierdie projek was daarom spesifiek daarop ingestel om 'n raamwerk te ontwikkel waarvolgens metaalveredelingsnywerhede vinnig en op hoë vlak kan vergelyk word aan die hand van volhoubaarheidsinligting wat in die openbare sfeer beskikbaar is. Daarvolgens kan 'n prioriteitslys van lewensvatbaarheidstudies oor nywerhede met ontwikkelingspotensiaal opgestel word.

Die raamwerk wat in hierdie navorsing ontwikkel is, bestaan uit 18 aanwysers wat almal dieselfde gewig dra – 6 aanwysers vir elk van die drie dimensies van volhoubare ontwikkeling. Hierdie aanwysers is saamgestel uit 30 sekondêre aanwysers wat uit die GRI G4-riglyne vir verslagdoening oor volhoubaarheid geneem is, en 10 sekondêre aanwysers wat spesifiek vir gebruik in hierdie raamwerk ontwikkel is. Die aanwysers is by wyse van 'n nie-kompenserende multi-kriteria saamvoegingsmetode saamgestel om 'n enkele indekswaarde vir elke dimensie van volhoubare ontwikkeling op te lewer. Nywerhede kan dus maklik vergelyk word met verwysing na slegs drie indekswaardes. Tabel 3.4 verskaf 'n opsomming van die aanwysers wat in die raamwerk gebruik is.

Platinum veredeling is gebruik as gevallestudie om die werkbaarheid en tekortkominge van die raamwerk te ondersoek. Spesifiek die plaaslike vervaardiging van katalitiese-omsetters en platinum juweliersware is vergelyk. Die navorsingsbevinding was dat die vervaardiging van katalitiese-omsetters in beide die ekonomiese en die sosiale dimensie beter vaar (met 92% en 81% sekerheid vir die onderskeie dimensies). Wat die omgewingsdimensie betref, vertoon die vervaardiging van platinum juweliersware beter (71% sekerheid). Die sekerheidsintervalle is bereken uit 10 000 iterasies in 'n Monte Carlo-simulasie wat gedoen is om te kwantifiseer watter invloed onsekerheid in die insetwaardes het op die uitkomste wat die raamwerk oplewer. Die bevinding dat die vervaardiging van katalitiese-omsetters in twee van die drie dimensies voordeliger behoort te wees, bevestig die prioriteite wat die huidige ontwikkelingsbeleid in Suid-Afrika volg. Die beleid fokus meer op die verdere ontwikkeling van die motornywerheid as die ontwikkeling van 'n platinum-juwelierswarenywerheid.

Op grond van die bevindings wat opgelewer is deur die raamwerk op hierdie platinumnywerhede toe te pas, is die gevolgtrekking gemaak dat die raamwerk inderdaad die vergelyking van nywerhede fasiliteer. Die raamwerk se sterk punte is, onder meer, dat dit maklik is om te gebruik, dat resultate vinnig bereken word en dat die aanwyserstruktuur hiërargies is, wat doeltreffende ontleding van resultate bevorder. Onder die tekortkominge van die raamwerk tel die moontlikheid dat subjektiwiteit kan insluip, dat onbekende onderliggende faktore in die insetwaardes verwringing van die opgelewerde resultate kan veroorsaak en dat die raamwerk afhanklik is van inligting wat in die openbare sfeer beskikbaar is.

Daar word aanbeveel dat die raamwerk verder getoets word deur nog gevallestudies te onderneem (dit op nog nywerhede toe te pas) om na te gaan of die raamwerk inderdaad al die nodige faktore in ag neem en die betrokke nywerhede behoorlik vergelyk. Verdere navorsing kan die moontlikheid ondersoek dat dit verbetering sal meebring as die raamwerk uitgebrei word om belangrike en unieke plaaslike faktore meer uitdruklik in ag te neem. Laastens word daar, op grond van die geslaagde toepassing van die raamwerk in hierdie gevallestudie, aanbeveel dat dit gebruik word om meer nywerhede te vergelyk en sodoende nuwe ontwikkelingsgeleenthede uit te wys en die ontwikkeling daarvan in Suid-Afrika te bevorder.

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Nomenclature

Variables

I	Indicator

Subscripts

i	Identifies a specific indicator
j	Identifies a specific group of indicators: $j = 1$: economic indicators $j = 2$: environmental indicators $j = 3$: social indicators
N	Indicates a normalised indicator
S	Indicates a sub-index
t	Refers to a specific year

Superscripts

Ref	Indicates a reference or benchmark value
$+$	Identifies an indicator with a positive impact on sustainable development (a higher value signals improvement)
$-$	Identifies an indicator with a negative impact on sustainable development (a lower value signals improvement)

Abbreviations

APDP	Automotive Production and Development Programme, South Africa
AHP	Analytic hierarchy process
BAP	Budget allocation process
BOD	Benefit of the doubt
CA	Conjoint analysis
C-K-Y-L	Condorcet-Kemeny-Young-Levenglick
COP	Communication on Progress
CR	Corporate responsibility

CSIR	Council for Scientific and Industrial Research
CSR	Corporate social responsibility
DEA	Data envelopment analysis
DMR	Department of Mineral Resources, South Africa
EIA	Environmental impact assessment
EW	Equal weighting
FA	Factor analysis
GBP	Great British Pound, £
GRI	Global Reporting Initiative
HFCT	Hydrogen and Fuel Cells Technologies
IFAA	Institute For African Alternatives
IIED	International Institute for Environment and Development
IISD	International Institute for Sustainable Development
IIRC	International Integrated Reporting Council
<IR>	Integrated Reporting
IRS	Impala Refining Services
MDGs	Millenium Development Goals
MMSD	Mining, Minerals and Sustainable Development
NCMC	Non-compensatory multi-criteria
OECD	Organisation for Economic Co-operation and Development
PCA	Principal components analysis
R&D	Research and development
SASB	Sustainability Accounting Standards Board
SD	Sustainable development
SDGs	Sustainable Development Goals
SG&A	Selling, general and administrative, in reference to cost
SMME	Small, medium or micro-sized enterprise
SWOT	Strengths, Weaknesses, Opportunities, Threats; used to evaluate the characteristics of a project
TBL	Triple bottom line
TTSE	Two Tiered Sustainability Equilibrium
UCM	Unobserved components models
UNGC	United Nations Global Compact
USD	United States Dollar, US$
USGS	United States Geological Survey
WBCSD	World Business Council for Sustainable Development
ZAR	South African Rand, R

Chapter 1

Introduction

This chapter serves to introduce the reader to the project described in this thesis. Some background and the rationale to this project are provided, followed by a summary of the research objectives and research questions addressed by the project. An overview of the scope and structure of this thesis concludes this chapter.

1.1 Background and rationale

South Africa is the wealthiest mining jurisdiction in the world, with its mineral wealth reported to be between US$2.5 and 4.7 trillion (Dworzanowski, 2013; Baartjes and Gounden, 2011). Its mineral endowment includes more than 80 per cent each of global chromium and platinum reserves, more than 20 per cent each of global manganese, vanadium and zirconium mineral reserves and close to 12 per cent of global gold reserves (South African Chamber of Mines, 2015). The comparative advantage brought about by these vast resources has, however, not been fully converted into a national competitive advantage and there appears to be a consensus that the direct and indirect value South Africa derives from its mineral resources can be much improved. The South African Chamber of Mines (2015), for example, reported that a total of 72.6 per cent of total commodity production in South Africa was exported without any local beneficiation[1] beyond production (amongst others 89.5 per cent of platinum group metals, 89.6 per cent of manganese and 90.8 per cent of iron ore was exported).

Increasing economic pressure to exploit this untapped potential, along with other national development considerations, has led the South African government to strongly pursue increased local beneficiation of its natural resources.

[1]Also referred to as 'economic beneficiation', meaning transformation of mined ore into higher value product that can be consumed locally or exported (Dworzanowski, 2013; South African Department of Mineral Resources, 2011).

Its formal commitment to this cause was inked in 2011 with the publication of the Department of Mineral Resources' 'Beneficiation Strategy For The Minerals Industry'. The Beneficiation Strategy identifies five strategic mineral value chains for which it discusses constraints and interventions in order to illustrate the value that South Africa can create by local beneficiation of its mineral resources.

This commitment to increased local beneficiation in South Africa forms the first part of the opportunity addressed by this research project as policymakers in South Africa (and abroad, where similar policies are being implemented) are now faced with the daunting task of selecting viable new industries that can be developed. These industries have to be carefully selected such that, if developed, it will create maximum sustainable value, taking not only economic value creation, but also potential social and environmental value creation and impacts, into account. The complexity of these considerations imply that a multiphase, iterative feasibility study process should be followed to sequentially narrow down the options until an optimal alternative can be chosen.

A typical feasibility study process can be divided into three phases: the conceptual or scoping phase, the preliminary or prefeasibility phase and the final or definitive phase (Noort and Adams, 2006). The focus of the study narrows with each consecutive phase, while the resources invested and the value created by the study increases with each phase. This multiphase and often iterative nature, however, requires considerable time, effort and funding (Heidenberger and Stummer, 1999; Mackenzie and Cusworth, 2007) and it would therefore be advantageous if the scope of the study can be narrowed as soon as possible, thereby limiting resource expenditure.

The second part of the opportunity addressed by this research arose with the flood of sustainable development information from a wide range of organisations into the public domain in recent years. This is a product of the global emphasis on sustainable business strategies and sustainability reporting that consequently became a worldwide norm (KPMG, 2013). This sustainability information is typically disclosed along with the annual financial publications of a company, either as part of a single consolidated report or as a separate report, often referred to as the 'sustainability' report. Sustainability reporting guidelines, analogous to typical financial reporting guidelines (the International Financial Reporting Standards, IFRS, for example) are widely used to structure sustainability reports.

As explained by Du Plessis and Bam (Forthcoming), an opportunity now exists to make use of this easily accessible information, which is available for many different incumbent industries, to inform investment decisions regarding the development of such industries elsewhere in the world. Specifically, the ease-of-access to sustainability information can be leveraged in order to facilitate the rapid comparison of development opportunities and thereby reduce the time, effort and capital invested in the feasibility study process. Such a comparison can specifically be of value during the scoping phase of the feasibility assessment process as the scope of the comparison and the accuracy of the conclusions drawn will likely not be sufficient to completely replace detailed feasibility studies. As the first phase of the process, the scoping phase aims to "define the potential of a project, eliminate those options that are unlikely to become optimal, and determine if there is sufficient opportunity to justify the investment required for further studies" (Noort and Adams, 2006). The scoping phase thus forms the basis of any further investigations into the feasibility of a development opportunity and the rapid, yet accurate, conclusion of this phase is therefore of pivotal importance.

Considering the above, the vision of this research is, ultimately, to enhance the efficiency of the feasibility study process by the development of a framework that facilitates the rapid comparison of development opportunities and identification of those development opportunities that likely have the most development potential. Application of this framework will allow the subsequent feasibility study steps to commence as soon as possible.

1.2 Research objectives & research questions

More specifically, this project aims to investigate the possibility of developing a framework that effectively facilitates the use of publicly available sustainability information to rapidly compare beneficiation development opportunities at national level. This overall objective is investigated by developing such a framework and applying it to a case study in order to evaluate its potential to be useful in decision-making.

The investigation starts with a literature study of important fields that form the foundation of the framework, followed by an extensive process of developing the framework and finally testing the utility of the developed framework as to evaluate its success in achieving the aforementioned primary objective. These three steps that together form the backbone of this investigation, are the three sub-objectives of the project.

Figure 1.1 illustrates the hierarchy of research objectives and research questions that were developed to guide this investigation. The three sub-objectives of the project are illustrated along with the research questions that, when answered, will fulfil each sub-objective.

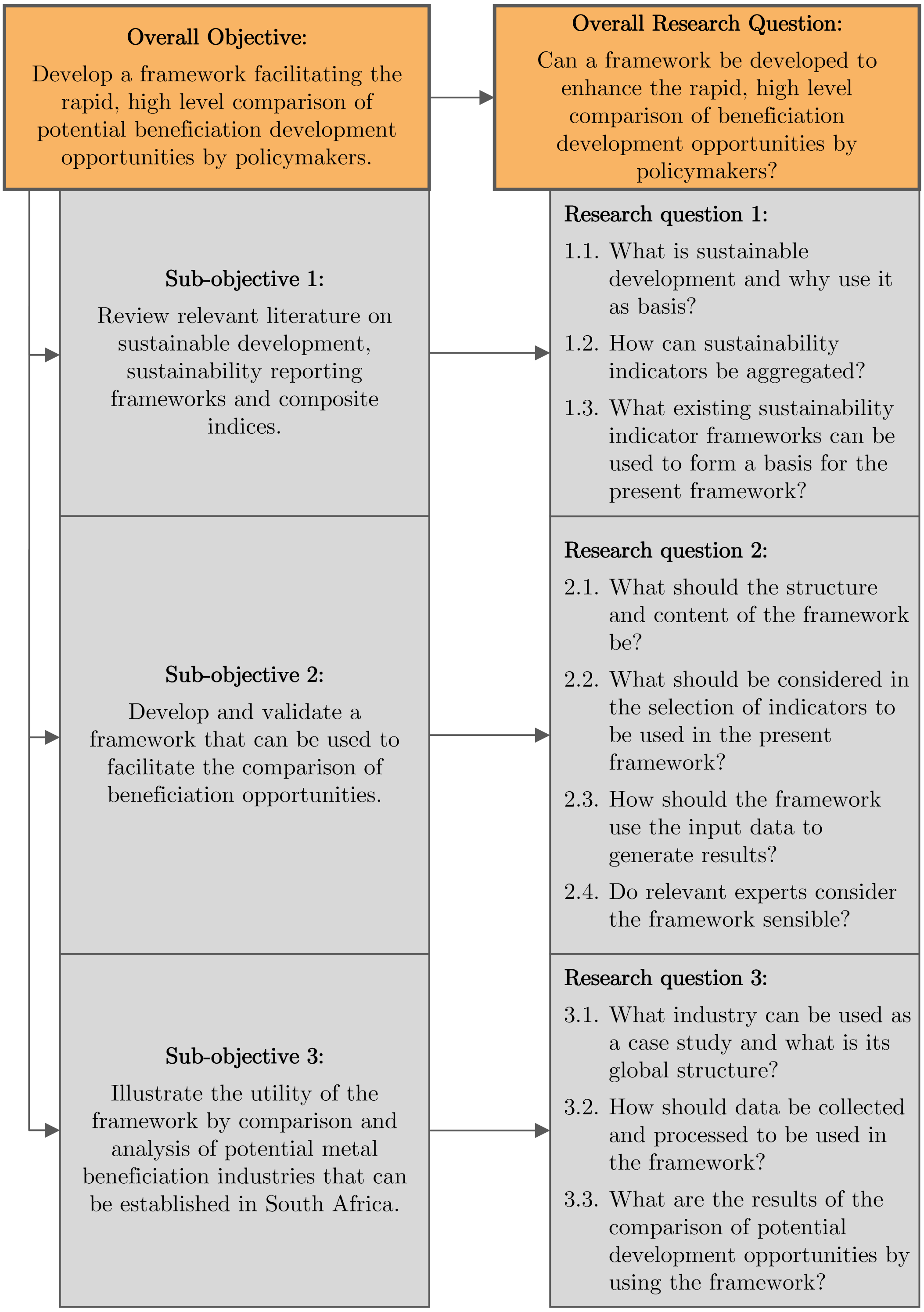


Figure 1.1: Research objective and research question hierarchy

1.3 Project scope

As apparent from the previous section, this project is primarily concerned with the development, validation and testing of the aforementioned framework. The framework is specifically aimed at:

- Rapid comparison of development opportunities by making use of publicly available sustainability information;
- High level assessment of opportunities as typically applicable to the scoping phase of a development project;
- Comparison of potential metal beneficiation industries, although the framework may possibly be applicable to other industries as well.

These characteristics are further discussed in Section 3.1 in Chapter 3 of this document.

The utility of the framework in a real-world application was evaluated through a case study methodology in which two platinum beneficiation industries were used. The results generated in this process was used to draw conclusions regarding the strengths and shortcomings of the framework. The reasons for using platinum beneficiation industries as case study are further elucidated in Chapter 4.

1.4 Thesis structure

The structure of this document is as follows:

Chapter 2: Sustainable development as foundation of the framework
This chapter introduces the concept of sustainable development and its assessment by making use of indicators. Aggregate and composite indicators as well as the process of aggregating indicators are then discussed, followed by a brief overview of some of the most prominent and relevant international sustainability reporting guidelines or frameworks.

Chapter 3: Development of the framework
Building on the theoretical background covered in the previous chapter, this chapter discusses the purpose, scope and structure of the framework, as well as the exact methodology followed in the development of the framework.

Chapter 4: Case study: Background
Following the development of the framework detailed in the previous chapter, this chapter describes the reasoning why platinum industries were chosen as a

case study to test the utility of the framework. This is followed by an extensive overview of the global platinum industry and the chapter then finally concludes by describing which specific platinum-consuming industries were used as case study industries and the reasoning behind these selections.

Chapter 5: Case study: Application of the framework
This chapter details the process of testing the utility of the framework. The data collection and scaling processes, as well as the process of conducting uncertainty analysis are described, followed by a discussion of the results generated by the framework. Finally, based on these results, the utility of the framework is evaluated in the form of a S.W.O.T. analysis.

Chapter 6: Conclusion and recommendations
The document is then concluded by a discussion of the conclusions and recommendations that can be made.

Figure 1.2 presents an outline of where each of the aforementioned sub-objectives of this project are addressed in this document.

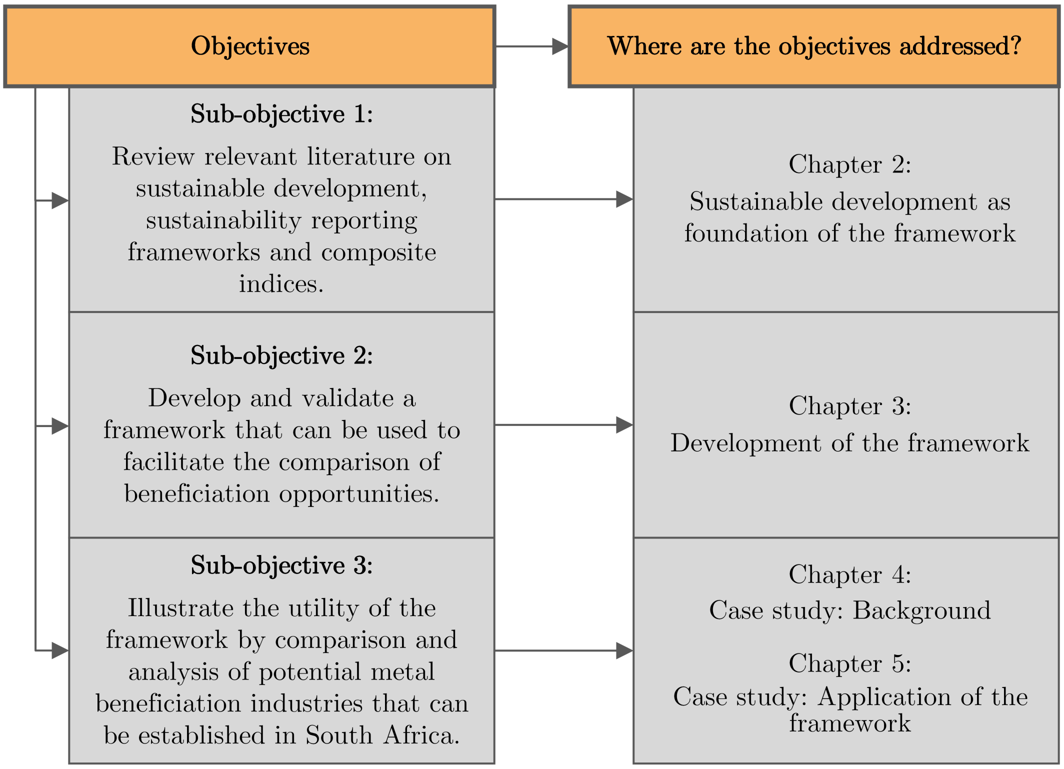


Figure 1.2: Overview of where each research sub-objective is addressed in this document

Chapter 2

Sustainable development as foundation of the framework

In the light of the ever-increasing global focus on sustainable development of industries it is considered imperative that the framework developed in this project consider all aspects of the potential value capture, not merely the economic aspects, as was historically often the case. Sustainability indicators spanning all three the spheres of sustainability should therefore be used to assess the potential value capture of different development opportunities. The extensive literature available on sustainable development and its measurement, as well as existing sustainability assessment frameworks, is briefly discussed in this chapter so as to lay the foundation for the development of the assessment framework described in subsequent chapters.

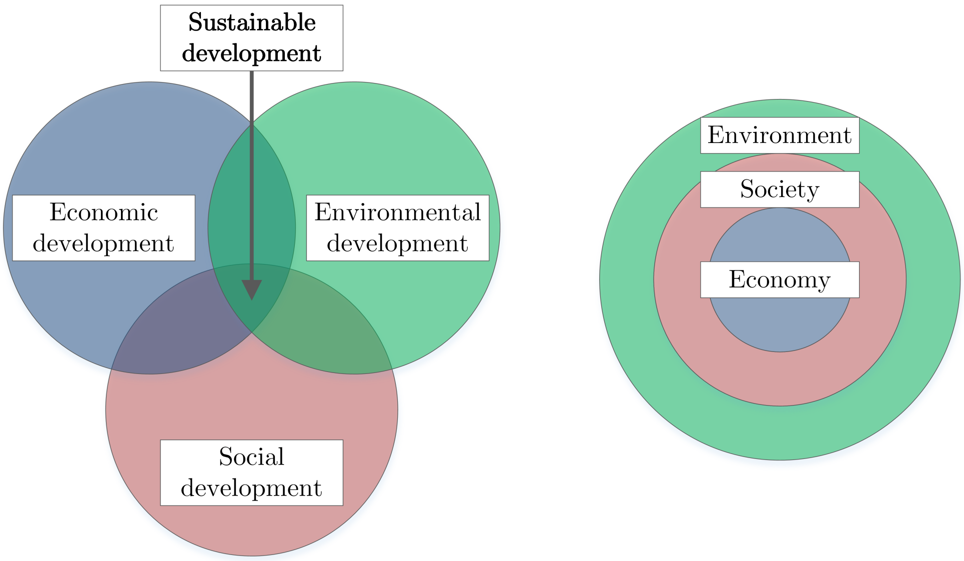
This chapter therefore starts with an introduction to the concept of sustainable development and its assessment by using sustainability indicators. This introduction is then followed by a discussion of the theory regarding aggregation of sustainability indicators and the choice of aggregation method. A brief overview of existing indicator frameworks relevant to the present project concludes this chapter.

2.1 Sustainable development

By the early 1980s, global concern about the rate at which the environment was degraded by industrial development was such that, in 1983, the General Assembly of the United Nations made an urgent call to formulate "A global agenda for change". The World Commission on Environment and Development was subsequently established and published its report titled "Our Common Future" in 1987. This report, commonly referred to as the Brundtland Report (after the chairman of the commission - Gro Harlem Brundtland), provided the definition for sustainable development (SD) that still remains the most common definition used globally (Carter and Rogers, 2008). Sustainable development was defined as development that took place such that the needs of the present generation is met without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). Sustainable development therefore refers to the process or path to achieve sustainability, with sustainability being the ideal dynamic state where a system has the capacity to maintain itself indefinitely (Hak *et al.*, 2012; Lozano, 2008). However, it is important to note that the terms 'sustainable development' and 'sustainability' are often used interchangeably in the literature (Lozano, 2008).

Although the focus of the sustainable development concept was initially on the protection of the natural environment, the Brundtland report already mentioned the importance of considering not only the environmental aspect, but also the social and economic aspects of development when attempting to become sustainable. Subsequently, in 1994, John Elkington coined the term "Triple Bottom Line" (TBL), referring to the need for corporations to not just focus on economic value addition, but also on the environmental and social value they add or destroy (Elkington, 1994). Figure 2.1 illustrates two widely used visual representations of the TBL of sustainability. Figure 2.1 (a) illustrates the triple bottom line as the union of sustainable economic-, environmental- and social development in a Venn diagram. Figure 2.1 (b) shows sustainability as represented by three concentric circles with the economy at the centre, as a subsystem of society, and society in the middle, as a subsystem of the outer, natural environment circle (Lozano, 2008).

These diagrammatic representations of sustainability are widely used, but their accuracy in fully representing the concept of sustainable development has been criticised by several sources, including Lozano (2008) and Pulselli *et al.* (2015). These authors note that representations such as those in Figure 2.1 does not include the temporal dimension of sustainability (does not consider change over time), which is explicitly included in the Brundtland report definition of sustainable development when it mentions the needs of "future generations" (World Commission on Environment and Development, 1987). Further, these representations consider sustainability to be compartmentalised and does not consider the interrelations within and among the three aspects. The Venn diagram representation further also wrongly presents the three aspects as substitutable, allowing trade-offs between the dimensions (reductions in one dimension in order to improve in another) (Pulselli *et al.*, 2015). In response to these shortcomings, several new (better) visual representations have been proposed, notably the three dimensional Two Tiered Sustainability Equilibrium (TTSE) representation by Lozano (2008) and the cubic structure by Pulselli *et al.* (2015).



(a) Venn diagram representation (b) Three concentric circles representation

Figure 2.1: Two widely used graphical representations of sustainable development (Lozano, 2008)

The exact structures of these new representations are not of importance in the present discussion as the exact meaning of sustainable development remains an ongoing debate (Parris and Kates, 2003). However, it has widely been accepted that sustainable development requires sustainability in terms of the economic, environmental and social spheres of development, in both the temporal and spatial dimensions. Sustainable development therefore requires sustainable economic, environmental and social performance at both a local and global level, for both the present and future generations (Azapagic and Perdan, 2000). Further, it is increasingly emphasised that when considering sustainable development, the interrelations within and among its different dimensions are of significant importance (Lozano, 2008).

The realisation that all three the dimensions of sustainability are of equal importance and should be considered holistically, in contrast to the historic compartmentalised view with an emphasis on environmental protection, signalled a paradigm shift regarding industry's view of sustainable development. This paradigm shift was accompanied by substantial efforts in industry to define sustainable business strategies (Azapagic and Perdan, 2000; Lozano, 2013). Following the widespread promotion and approval of sustainable business strategies, sustainability reporting, also commonly referred to as Corporate (Social) Responsibilty (CR) Reporting, has been growing steadily. Corporate responsibility reports typically report the sustainable development progress of a corporation in all the dimensions of the triple bottom line on a periodic basis, most often as part of the annual financial reports. In 2013, KPMG

International published the eigth edition of the KPMG Survey of Corporate Responsibility Reporting which surveyed 4100 companies in 41 countries. The report found that 71 per cent of companies surveyed and 93 per cent of the world's largest 250 firms publish corporate responsibility reports on a regular basis. The number of companies publishing corporate responsibility reports was found to have increased by 7 per cent since the previous survey in 2011. The report stated that "CR reporting is now undeniably a mainstream business practice worldwide..." (KPMG, 2013).

2.2 Sustainability indicators

Sustainable development progress has to be measured, not only for sustainability reporting purposes, but primarily to be able to identify areas where acceptable progress towards specific goals is being made, as well as areas where progress is inadequate. Quantification of sustainable development progress is typically done by using sustainability indicators. In essence, sustainability indicators aim to reduce the enormous number of complex interrelationships in our dynamic environment to a manageable amount of meaningful information, such that indicators become a useful tool for communication, decision making and management, advocacy, participation and consensus building, and research and analysis (Ciegis *et al.*, 2009; Parris and Kates, 2003; Singh *et al.*, 2009).

Based on the discussion in Section 2.1 above, integrated sustainability assessment, taking the complex interrelationships between the three dimensions of sustainability into account, is required in order to gain a comprehensive and objective view of sustainable development progress (Azapagic, 2004; Hak *et al.*, 2012). Ideally, a single sustainability indicator should be able to holistically capture information regarding all three the spheres of sustainability and the complex interrelationships between them, thereby providing a single measure that captures the dynamics of the entire system. However, the concept of sustainable development is so diverse, complex and extensive in nature that the development of such an all-encompassing indicator is deemed impossible (at the present moment, at least) (Ciegis *et al.*, 2009; Waas *et al.*, 2014).

Due to the dynamic and complex nature of the systems being considered, even when not attempting to develop an ideal, integrated sustainability indicator, measurement of progress is still not a trivial operation. As a result, sustainability indicators is a growing field of research and a very large number of indicators have been developed by a wide range of sources. This is apparent from the Compendium of Sustainable Development Indicator Initiatives, revised in 2002 to 2003, which at that time already listed 895 different sustainability indicator initiatives, ranging from local to international in scope, used worldwide to assess sustainability performance (IISD, 2004). Each indicator typically considers one or a few specific aspects of sustainable development and have specific inherent advantages and disadvantages to its use. It has therefore become common practice to choose and combine a number of indicators in order to measure progress in all three the dimensions of sustainable development (Ciegis *et al.*, 2009; Waas *et al.*, 2014). The use of integrated indicators has also been promoted by several sources. Integrated indicators are single measures that aim to reflect the interrelationships between different aspects of sustainability (for example, value added per mass of material used, relating the economic and environmental aspects) and therefore present an important step in the direction of gaining a holistic view of sustainable development progress (Azapagic, 2004; Fonseca *et al.*, 2013*b*; Krajnc and Glavič, 2005; Waas *et al.*, 2014).

However, the usefulness of a large number of individual indicators in decision-making, irrespective of whether they are simple- or integrated indicators, is often limited by the inability of the user to draw an objective and transparent conclusion by considering all the individual indicators. Therefore, from a scientific viewpoint, it is desirable to be able to combine all the indicator values into a single value that captures the essence of all the individual values (Sikdar, 2009). The potential value of such aggregated indicators has attracted some research attention and many different approaches to objectively aggregate indicators have been proposed and discussed (Brandi *et al.*, 2014; Krajnc and Glavič, 2005; Sikdar, 2009; Sikdar *et al.*, 2012; Zhou *et al.*, 2012). The condensed and aggregated single metric thus obtained is commonly referred to as a sustainability index. Section 2.3, below, discusses the aggregation of indicators further.

Figure 2.2 illustrates the progression from primary data to knowledge, facilitated by the use of sustainability indicators and/or indices (Waas *et al.*, 2014).

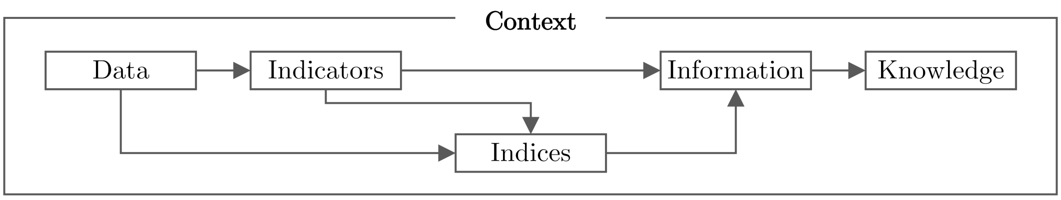


Figure 2.2: The progression from primary data to knowledge (Waas *et al.*, 2014)

Note that some ambiguity exists with regard to the terminology used to describe aggregated indicators and indices. Hak *et al.* (2012) defines an 'aggregated indicator' as an indicator that combines a number of components (data or sub-indicators) defined in the same units (for example Gross Domestic Product). The term 'composite indicator' is defined as an indicator that combines various (complex) aspects of a given phenomenon into a single number with a common unit (for example life expectancy). Finally, it is stated that an index generally refers to a single dimensionless number produced by transformation of data measured in different units into a single number (for example Air Quality Index). These terms are, however, not used strictly according to the understanding of Hak *et al.* (2012) in all literature.

Furthermore, it has been warned that aggregation of indicators can lead to deceptive results due to the inherent subjectivity of the aggregation process (Singh *et al.*, 2009). In an attempt to reduce subjectivity, Zhou *et al.* (2012) used sensitivity analysis to compare different aggregation schemes in order to identify the method that results in an aggregated indicator with the highest sensitivity to individual indicator values from which it is calculated. Waas *et al.* (2014) notes that sustainability indicators and indices are "in every instance a social construction, reduction and simplification of the complex reality and its many uncertainties and risks...". They correctly point out that sustainability indicators will by definition always remain reductionist tools, in spite of widespread recommendation of and attempts to find holistic approaches. They further also stress the importance of avoiding the situation where the use of sustainability indicators creates a virtual reality that is blindly believed by decision-makers.

2.3 Aggregation of sustainability indicators

Sustainability analyses often rely on evaluation of different multidimensional states of a system in order to find the alternative that would (most effectively) allow sustainable development of the system. Such analyses are typically not trivial, with different, often contrasting, levels of importance and development trends associated with various aspects of the system. If the system is characterised by a finite number of quantitative metrics (or sustainability indicators, as is often the case), it is desirable from a decision-making point of view to aggregate the metrics into a single value reflective of the state of the system. Calculation of such aggregate values resulting from (or expected to result from) different decisions allow easy and comprehensive comparison of different resultant system states, facilitating more objective decision-making (Brandi *et al.*, 2014; Sikdar, 2009). Therefore not surprisingly, the aggregation of sustainability indicators into composite indices has attracted considerable research attention, although this practice has also been criticised. Critics often point out that composite indicators are too subjective, possibly significantly influenced by the choice of indicators, normalization method, weighting scheme and aggregation method (OECD and European Commission, 2008; Zhou *et al.*, 2012).

In attempts to improve the credibility of the aggregation process, several aggregation methodologies have been proposed (Brandi *et al.*, 2014; Krajnc and Glavič, 2005; Sikdar, 2009; Sikdar *et al.*, 2012; Zhou *et al.*, 2012). Further, the Organisation for Economic Co-operation and Development (OECD) published its "Handbook on Constructing Composite Indicators" in 2008, with the aim of providing guidance in the construction and use of composite indicators, specifically focussing on composite indicators used to rank and compare country performance (OECD and European Commission, 2008). Figure 2.3, below, provides a somewhat simplified overview of the typical steps followed in these aggregation processes, as well as the composing structure of a composite index.

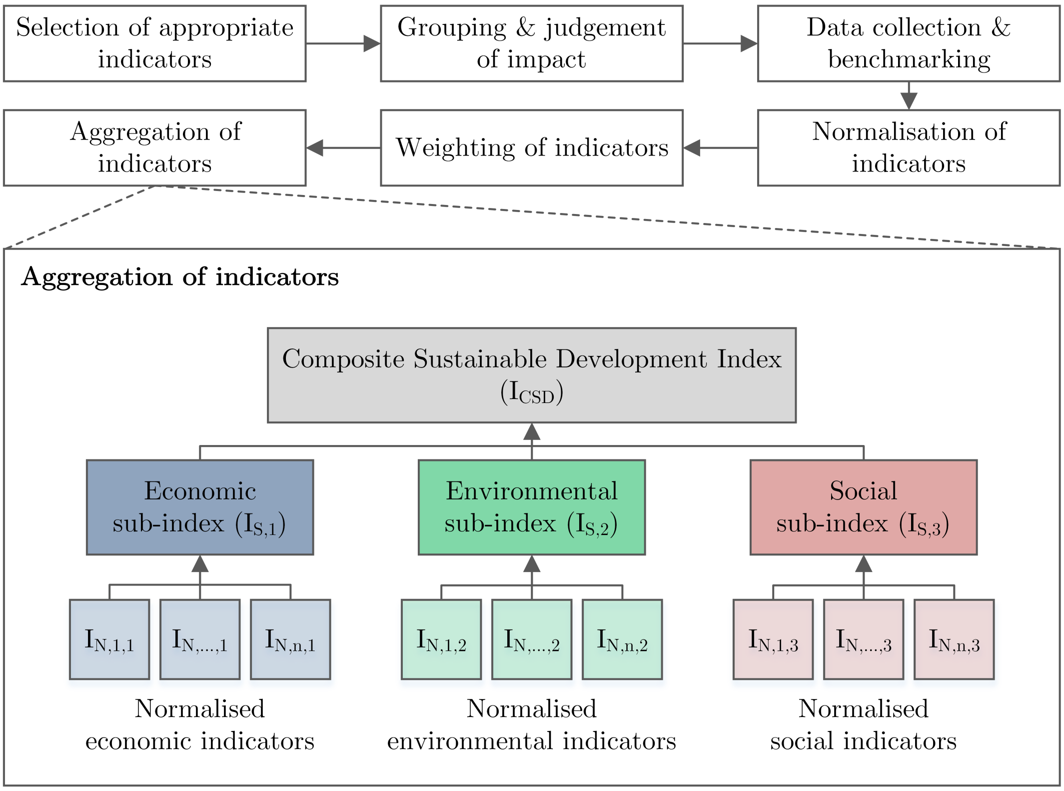


Figure 2.3: Typical process of aggregating sustainability indicators into a composite sustainable development index (adapted from Krajnc and Glavič (2005) and Zhou *et al.* (2012))

The Handbook on Constructing Composite Indicators (OECD and European Commission, 2008) presents 10 steps to construct and test a composite index. This handbook importantly notes that each individual step is of great importance, but that coherence in the whole process is also vital. Therefore, it must be ensured that the most appropriate methods are chosen for each step, but also that the chosen methods fit together well.

The steps in the aggregation process, as illustrated in Figure 2.3, will be discussed in the subsequent sections. Section 2.3.1 discusses the first three steps illustrated in Figure 2.3, after which Sections 2.3.2, 2.3.3 and 2.3.4 discuss the last three illustrated steps.

2.3.1 Preparation

Some steps, referred to as 'preparatory' steps here, have to be completed in order to ensure the objective of aggregation process is clear, relevant data is available and the inherent strengths and weaknesses of the underlying indicators are known.

OECD and European Commission (2008) states that the first step in the construction of a composite index should be the development of a theoretical framework defining the purpose of the composite index, the sub-groups it consists of and selection criteria for the underlying indicators. The selection of the underlying indicators is of particular importance as the strengths and the weaknesses of the composite indicator largely derive from the quality of the indicators it is composed of. OECD and European Commission (2008) devotes considerable attention to assuring quality in the construction of a composite indicator and notes that accuracy, timeliness and credibility are the three most prominent quality aspects influenced by the selection of indicators (the reader is kindly referred to OECD and European Commission (2008) for comprehensive coverage on assuring composite indicator quality).

Different approaches for selecting indicators can be used. Niemeijer (2002) states that the underlying indicators used to construct a composite indicator are generally selected according to one of two approaches: (1) the data-driven approach, where data availability is the central selection criteria when selecting indicators, and (2) the theory-driven approach, where it is attempted to select the best possible combination of indicators to describe the system (taking the availability of data into account, amongst other factors). Zhou *et al.* (2012) adds a third approach: the policy-driven approach, where indicators are selected specifically to comprehensively measure and assess the impact of a certain policy.

After selection of the appropriate indicators, the contribution measured by each indicator has to be judged in order to establish which indicators indicate positive impacts and which indicate negative impacts (Zhou *et al.*, 2012). The nature of the impact has an influence on the subsequent normalisation and aggregation steps.

Finally, a reference value or benchmark has to be established for each indicator. Brandi *et al.* (2014) states that: "The concept of sustainability is always relative" and it is therefore necessary to choose a reference system or establish benchmarks for the indicators. Comparison of the analysis results for a specific situation with the benchmark will then give an indication as to whether the situation is more or less favourable from a sustainable development point of view (Brandi *et al.*, 2014; Zhou *et al.*, 2012).

OECD and European Commission (2008) also includes the imputation of missing data and multivariate analysis of the data set before the subsequent normalisation step. Imputation of missing data becomes important in the case that missing data hinders the development of the composite indicator, while multivariate analysis (for example principal component analysis or cluster analysis) is done in order to assess the suitability of the data set and to facilitate a better understanding of the implications of the methodological choices in the construction of the composite indicator.

2.3.2 Normalisation of indicators

The indicator values have to be normalised prior to aggregation into a composite value as the units of measure of the indicators usually differ. Many different approaches to normalisation are used in literature. Krajnc and Glavič (2005) state that normalisation can be done by dividing each indicator with its average value over the time period under consideration. They further also suggest normalisation by dividing each indicator with the difference between its maximum and minimum value (this method is also discussed by OECD and European Commission (2008), Sikdar *et al.* (2012) and Zhou *et al.* (2012)). Finally, Krajnc and Glavič (2005) also note that normalisation can be done by other methods, such as normalisation with a benchmark or maximum-potential value (this method is also used by Sikdar *et al.* (2012)). Further, the percentage of annual differences over consecutive years can also be used to normalise indicator values (Zhou *et al.*, 2012). All these methods, amongst others, are also discussed by OECD and European Commission (2008). Table 2.1 summarises five of the most common methods used for normalisation applicable to the present project.

The first method in Table 2.1 (Equation 2.1), ranking, is the simplest normalisation technique and allows comparison of relative positions of different indicators for each case. However, the absolute performance of each case is not taken into account (OECD and European Commission, 2008) and therefore this normalisation method may produce deceptive results (the size of the

Table 2.1: Some common normalisation methods (Krajnc and Glavič, 2005; OECD and European Commission, 2008; Zhou *et al.*, 2012)

Ranking:	$I_{N,i,j,t} = Rank(I_{i,j,t})$	(2.1)
Average:	$I^{+}_{N,i,j,t} = \frac{I^{+}_{i,j,t}}{\overline{I}^{+}_{i,j}}$	(2.2)
	$I^{-}_{N,i,j,t} = \frac{I^{-}_{i,j,t}}{\overline{I}^{-}_{i,j}}$	(2.3)
Distance to a reference:	$I^{+}_{N,i,j,t} = \frac{I^{+}_{i,j,t}}{I^{Ref}_{i,j}}$	(2.4)
	$I^{-}_{N,i,j} = \frac{I^{Ref}_{i,j}}{I^{-}_{i,j,t}}$	(2.5)
Min-Max:	$I^{+}_{N,i,j,t} = \frac{I^{+}_{i,j,t} - min(I^{+}_{i,j})}{max(I^{+}_{i,j}) - min(I^{+}_{i,j})}$	(2.6)
	$I^{-}_{N,i,j,t} = 1 - \frac{I^{-}_{i,j,t} - min(I^{-}_{i,j})}{max(I^{-}_{i,j}) - min(I^{-}_{i,j})}$	(2.7)
Percentage of annual differences over consecutive years:	$I^{+}_{N,i,j,t} = \frac{I^{+}_{i,j,t} - I^{+}_{i,j,t-1}}{I^{+}_{i,j,t-1}}$	(2.8)
	$I^{-}_{N,i,j,t} = \frac{I^{-}_{i,j,t-1} - I^{-}_{i,j,t}}{I^{-}_{i,j,t-1}}$	(2.9)

difference between different cases is not reflected).

Normalisation by using the average or a reference value (Equations 2.2 & 2.3, and 2.4 & 2.5 in Table 2.1, respectively) is similar. Note that when making use of a reference value, the reciprocal of the equation for indicators measuring a postive impact on sustainable development (higher values are desirable) is used for indicators measuring a negative impact on sustainable development (lower values are desirable) (Zhou *et al.*, 2012). This is done such that more desirable values, irrespective of the impact that the indicator measures, always have higher normalised values, thereby ensuring that indicators measuring negative impacts and those measuring positive impacts does not offset each other during aggregation. Using the average value typically result in strictly positive normalised indicator values, centred around a value of 1. When making use of a reference value, often a maximum-potential or benchmark value, the reference value can be chosen such that all normalised indicator values range from zero to one, or that all the normalised values are small (which can be desirable for some aggregation methods, such as geometric aggregation, as discussed in Section 2.3.4). Benchmark values can be defined by using standards for a specific sector, targets to be reached in a given time frame, local legal regulations, typical values reported by relevant similar organisations or any other relevant documents (OECD and European Commission, 2008; Zhou *et al.*, 2012).

The mininum-maximum (min-max) normalisation method (Equations 2.6 & 2.7) subtracts the lowest indicator value and divides by the range between the highest and lowest indicator values, thereby resulting in normalised indicator values ranging from zero to one. Note that, once again, the equation used for indicators measuring positive impacts differs from the equation used for indicators measuring negative impacts. This once again ensures that more desirable values produce larger positive normalised values. This normalisation method can be useful to widen the range of indicators lying in a small interval, accentuating the effect of the values on the composite indicator. However, normalisation by this method can also result in distorted normalised values if extreme values or outliers are present in the data set.

The last method in Table 2.1 (Equations 2.8 & 2.9) makes use of the percentage of annual differences over consecutive years. The equation once again differs between indicators measuring positive impacts and those measuring negative impacts. This method of normalisation allows tracking of sustainable development progress over consecutive years, but results in the loss of data for the first year as this cannot be normalised. This method can therefore only be used when data for a number of years is available (OECD and European Commission, 2008; Zhou *et al.*, 2012).

2.3.3 Allocation of weights

The allocation of different weights to different indicators allows the effect of indicators that are deemed more important than others, perhaps due to industry-specific strategy or national policy, to be emphasised in the composite index. Many different techniques to establish appropriate weights for indicators are discussed in literature. Generally, weighting methods are either derived from statistical models or from participatory methods. Statistical methods makes use of statistical analysis of large datasets and include principal components analysis (PCA), factor analysis (FA), data envelopment analysis (DEA), the benefit of the doubt (BOD) approach and unobserved components models (UCM). Participatory methods makes use of expert knowledge, typically tapped through consultation of experts through interviews or questionnaires. Common participatory methods include the budget allocation process (BAP), analytic hierarchy process (AHP) and conjoint analysis (CA) (OECD and European Commission, 2008).

Although the above-mentioned techniques can be used for allocation of weights, it is most common to use equal weighting (EW) of all indicators. This implies that all indicators are of equal importance in the composite, as would typically be desirable with sustainability indicators where all the dimensions are of equal importance to ensure progress toward sustainability (Brandi *et al.*, 2014). However, equal weighting can also disguise the absence of statistical or empirical basis for weight allocation. Furthermore, if indicators are grouped into different dimensions and the dimensions consist of different numbers of indicators, equal weighting can result in an unbalanced composite index structure where dimensions consisting of more indicators have a higher weight. In the case that two or more variables have a high degree of correlation, aggregating indicators measuring these variables will introduce a degree of double counting in the composite index. This effect can be reduced by testing indicators for statistical correlation and choosing indicators will low correlation, or by adjusting weights such that the combined weight of the correlating indicators in the composite index is reasonable. However, it is important to note that although some indicators may have a high degree of correlation, it would depend on the specific phenomenon that the composite index attempts to capture whether this correlation is acceptable and how it should be handled. That is, the suitability of a set of indicators should be assessed based on the phenomenon they all aim to capture and not only by statistical analysis (OECD and European Commission, 2008).

In the case that equal weighting is deemed undesirable, various methods, as mentioned above, can be used to allocate different weights to different indicators. The statistical quality of the data can be used for this purpose – higher weights can be allocated to statistically more reliable data, although this will favour readily available indicators and will penalise aspects that are harder to measure and quantify reliably. Any of the above-mentioned statistical techniques can also be used, given sufficient and good quality data is available. Principal components analysis or factor analysis can, for example, be used to group individual indicators according to their degree of correlation. These methods can of course not be used to allocate weights if no correlation exists between indicators (OECD and European Commission, 2008).

Apart from equal weighting, participatory methods are also widely used, due to their simplicity and transparency. The budget allocation process, for example, determines indicator weights based on expert opinion. In this method, the experts are given a budget of N points to be distributed between a number of individual indicators, allocating a larger portion of the budget to indicators which they deem to be more important, based on their experience and subjective judgement (OECD and European Commission, 2008; Zhou *et al.*, 2012). It is, of course, important that the group of experts represents a wide spectrum of knowledge and experience to ensure that the resultant weighting scheme is as objective as possible. Based on the group of experts consulted, the resulting weighting scheme may reflect specific local or regional preferences and conditions, and the weighting may therefore not be applicable to other regions (Zhou *et al.*, 2012).

The analytic hierarchy process (AHP), widely accepted as a leading multi-attribute decision model, is another participatory method that can be used to allocate weights to individual indicators. The AHP basically relies on sequential pairwise comparison of all indicators, facilitated by the question: 'Which of the two indicators in the pair being considered is of greater importance to sustainable development for the system?'. The intensity of preference is expressed on a scale from 1 to 9, with 1 indicating equal importance and 9 indicating one indicator is 9 times more important than the other. Comparison of each indicator with all the other indicators in this way produces a positive reciprocal matrix, which can be normalised to produce a matrix of relative weights for all indicators considered. The consistency of the matrix can be checked by calculating a consistency ratio, thereby limiting the possibility of careless errors or exaggerated judgements (Krajnc and Glavič, 2005).

2.3.4 Aggregation of indicators

Several different aggregation methods can be used. Linear aggregation, typically calculated as the weighted sum of the normalised indicators, is widely used due to its simplicity, transparency and easy understanding. However, with the use of linear aggregation an often neglected complication arises regarding the interpretation of indicator weights. Indicator weights are most often perceived to reflect the relative importance of the associated indicator, however, when using compensatory aggregation methods such as linear aggregation, indicator weights express substitution rates (trade-offs) between indicators and not the relative importance. As a result, linear aggregation follows a compensatory logic, meaning that sufficiently good performance of some indicators can compensate for poor performance of others (referred to as compensability). Compensability is often an undesirable property as, for example in the case of sustainable development, good economic performance cannot compensate for a loss in the social or environmental dimensions (OECD and European Commission, 2008; Zhou *et al.*, 2012).

The use of geometric aggregation, calculated as the product of the normalised individual indicators, each to the power of its weight, partially addresses the issue of compensability. While compensability is constant for linear aggregation, it is partial for geometric aggregation and compensability is lower for indicators with low values. The inconsistency in perceived meaning of indicator weights therefore persists. Further, multiplicative aggregation methods such as geometric aggregation cannot be used if the values of some indicators are zero, thus further limiting its utility. However, when using geometric aggregation, an increase in a low indicator value makes a more profound difference in the composite index value than an increase in a higher value and therefore this method motivates improvement of poor scores, making it a useful method in some instances (OECD and European Commission, 2008; Zhou *et al.*, 2012).

To overcome the problems regarding compensability and the meaning of weights, a non-compensatory multi-criteria (NCMC) approach can be used. Such methods allows a compromise to be found between two or more equally legitimate and -important goals, without compensability. As such, indicator weights are interpreted as importance coefficients in non-compensatory methods (OECD and European Commission, 2008). According to OECD and European Commission (2008) a NCMC approach makes use of two steps:

1. Construction of an outranking (impact) matrix by pairwise comparison of alternatives at the hand of the whole set of individual indicators used to characterise alternatives;

2. Ranking of alternatives based on their relative performance as captured in the impact matrix.

For clarity, these steps can be presented in a more formal manner, as follows. Let E denote the outranking matrix and e_{ab} any generic element of E resulting from the pairwise comparison of alternatives a and b ($a \neq b$) according to all the Q individual indicators (i), then (OECD and European Commission, 2008):

$$e_{ab} = \sum_{i=1}^{Q} (w_i(Preference_{ab}) + \frac{1}{2} w_i(Indifference_{ab})) \qquad (2.10)$$

where $w_i(Preference_{ab})$ and $w_i(Indifference_{ab})$ are the weights of individual indicators presenting a preference or indifference relation, respectively. Thus, the score of alternative a is the sum of the weights of individual indicators for which this alternative performs better than alternative b, as well as the sum of half of the weights of indicators for which both alternatives perform equally well (OECD and European Commission, 2008).

To illustrate the use of Equation 2.10, assume 5 equally weighted indicators ($\sum_{i=1}^{Q} w_i = 1$, thus in this case each indicator weighs $\frac{1}{5}$) are used to compare 3 alternatives. Assuming higher indicator values are desirable in this case, consider the hypothetical data set given in Table 2.2.

Table 2.2: Hypothetical alternatives and corresponding indicator values to illustrate the use of Equation 2.10

	Alternative a	Alternative b	Alternative c
Indicator 1	10	8	9
Indicator 2	10	7	8
Indicator 3	10	6	11
Indicator 4	7	10	8
Indicator 5	4	6	8

From the data in Table 2.2 it is clear that alternative a performs better than alternative b in 3 of the 5 indicators, thus alternative a receives a score of $3 \times \frac{1}{5} = \frac{3}{5}$ and conversely, alternative b receives a score of $1 - \frac{3}{5} = \frac{2}{5}$. Further, it is observed that alternative a outperforms alternative c in 2 indicators and alternative b outperforms alternative c in 1 indicator. As a result, the outranking matrix will look as presented in Table 2.3.

Table 2.3: Outranking matrix to illustrate the use of Equation 2.10

	Alternative a	Alternative b	Alternative c
Alternative a	0	$\frac{3}{5}$	$\frac{2}{5}$
Alternative b	$\frac{2}{5}$	0	$\frac{1}{5}$
Alternative c	$\frac{3}{5}$	$\frac{4}{5}$	0

Following the construction of the outranking matrix, the evaluated alternatives can be ranked. Although different ranking methods can be used, OECD and European Commission (2008) recommends the use of the Condorcet-Kemeny-Young-Levenglick (C-K-Y-L) ranking procedure. This ranking procedure is based on the maximum likelihood concept, such that the final ranking with the maximum pairwise support is selected. That is, the selected ranking is the ranking supported by the maximum number of individual indicators for each pairwise comparison, summed over all pairs of alternatives (OECD and European Commission, 2008).

This ranking method does not make use of the plurality rule where an alternative that is ranked first most often is deemed to be the superior alternative. Rather, the C-K-Y-L procedure takes into account not only the indicators in which an alternative performs very well, but also those in which it performs very poorly. As such, an alternative that ranks very high in some indicators and very low in others will likely not be found to be the superior alternative (as would often be the case if the plurality rule is applied). Therefore, this method does not select the superior alternative simply by summing the scores from the outranking matrix and choosing the one with the highest score (OECD and European Commission, 2008).

The C-K-Y-L ranking procedure can be mathematically described, as follows. Comparing M alternatives results in an $M \times M$ outranking matrix, with $M!$ different rankings possible. Let R denote the set of all possible rankings, $R = \{r_m\}$ with $m = 1, 2, ..., M!$. A score, φ_m, can be calculated for each ranking, r_m, as the sum of e_{ab} over all the $\binom{M}{2}$ pairs of alternatives. Thus (OECD and European Commission, 2008),

$$\varphi_m = \sum e_{ab} \; where \; a \neq b, m = 1, 2, ..., M! \; and \; e_{a,b} \in r_m \tag{2.11}$$

The final ranking $(r*)$ is attained as (OECD and European Commission, 2008):

$$r^* \leftrightarrow \varphi^* = max \sum e_{ab} \; where \; e_{ab} \in R \tag{2.12}$$

To make this more palpable, consider the outranking matrix given by Table 2.3. As 3 alternatives are compared, $3! = 6$ possible rankings exist (as shown in Table 2.4). Consider the ranking $c \rightarrow a \rightarrow b$ (c is ranked first, followed by a, then b). For this ranking, applying Equation 2.11 to Table 2.3, it is observed that comparison of alternative c to alternative a and b yields $\frac{3}{5}$ and $\frac{4}{5}$, respectively (overall $\frac{7}{5}$). Subsequent comparison of alternative a to alternative b yields $\frac{3}{5}$. The ranking $c \rightarrow a \rightarrow b$ therefore attains a total score of $\varphi_1 = \frac{7}{5} + \frac{3}{5} = \frac{10}{5} = 2$. Similarly, when considering the ranking $b \rightarrow a \rightarrow c$, it is observed that comparison of alternative b to alternatives a and c yields $\frac{2}{5}$ and $\frac{1}{5}$, respectively (overall $\frac{3}{5}$). Subsequent comparison of alternative a and c yields

Table 2.4: Possible rankings and associated scores based on the C-K-Y-L ranking procedure

Ranking	**Score**
$c \rightarrow a \rightarrow b$	$\frac{10}{5}$
$c \rightarrow b \rightarrow a$	$\frac{9}{5}$
$a \rightarrow c \rightarrow b$	$\frac{9}{5}$
$b \rightarrow c \rightarrow a$	$\frac{6}{5}$
$a \rightarrow b \rightarrow c$	$\frac{6}{5}$
$b \rightarrow a \rightarrow c$	$\frac{5}{5}$

$\frac{2}{5}$. The ranking $b \rightarrow a \rightarrow c$ therefore attains a total score of $\varphi_6 = \frac{3}{5} + \frac{2}{5} = \frac{5}{5}$. Table 2.4 presents the scores attained by all the possible rankings, following this methodology. From Table 2.4 it is clear that ranking $c \rightarrow a \rightarrow b$ attains the highest score and is therefore the ranking of the alternatives supported by the most pairwise comparisons (and is therefore deemed the most likely ranking, based on the maximum likelihood concept).

When making use of the C-K-Y-L ranking procedure, it is important to note that, due to the underlying assumptions of the procedure, no indicator weight can constitute more than 50% of the total weights and subsequently, if indicator weights are derived for different dimensions, no dimension should weigh more than 50% of the total weights (the reader is kindly referred to OECD and European Commission (2008) and Munda (2005) for more details in this regard).

When following the aggregation procedure as described above, NCMC aggregation overcomes some of the problems that occur when additive or multiplicative aggregation techniques are used. For example, no compensability is allowed and weights are interpreted to indicate relative importance, not trade-offs between indicators. This method further also allows the use of both quantitative and qualitative information and does not require normalisation of data, thereby limiting subjectivity in the aggregation process. However, when using NCMC the magnitude of differences between indicator values for alternatives are not taken into account and, as such, the resulting composite indicator does not indicate the degree of superiority or inferiority of one alternative compared to another. Furthermore, in some situations cycles may arise in the final ranking where, for example, alternative a is preferred to b, b is preferred to c and c is preferred to a. This occurrence of cycles has also been found for the AHP with indicators. A final drawback of this aggregation method is the computational cost. Ranking of 3 alternatives requires only $3! = 6$ different rankings to be considered, however, when 5 or 10 alternatives have to be ranked, $5! = 120$ or $10! = 3628800$ rankings have to be considered. As such, the use of this method is quickly limited to comparison of few alternatives if computational capability is limited (although numerical method algorithms can be applied to minimise this problem) (OECD and European Commission, 2008).

Zhou *et al.* (2012) illustrates the use of a NCMC approach in the context of comparing sustainability performance over a period of time. The user is kindly referred to this paper for a practical, real-world example of the application of an NCMC aggregation method.

It is very important to note that some normalisation-, weighting- and aggregation methods are incompatible and the combination can therefore not be used. Zhou *et al.* (2012) concludes that as the minimum-maximum normalisation method will unavoidably result in a zero value for the minimum value and therefore produce a zero value during geometric aggregation, this combination should not be used. They further also recommend that the percentage of annual differences over consecutive years is not used for normalisation due to "its limited compatibility and information loss during the first year". Further, OECD and European Commission (2008) presents a table summarising

Table 2.5: Compatibility between weighting and aggregation methods (from OECD and European Commission (2008))

Weighting methods	**Aggregation methods**		
	Linear	Geometric	Multi-criteria
EW	Yes	Yes	Yes
PCA/FA	Yes	Yes	Yes
BOD	Yes[a]	No	No
UCM	Yes	No	No
BAP	Yes	Yes	Yes
AHP	Yes	Yes	No[b]
CA	Yes	Yes	No[b]

[a]Normalised with the Min-Max method

[b]At least with multi-criteria methods requiring weights as importance coefficients

the compatibility of different weighting- and aggregation methods. This table is reproduced in Table 2.5 for convenience.

2.3.5 Additional steps

Several analysis steps that can be performed after the aggregation step are discussed by OECD and European Commission (2008). These steps include uncertainty and sensitivity analysis, analysis of the main drivers of overall performance, correlation of the composite indicator with existing indicators and visualisation of results. The reader is kindly referred to OECD and European Commission (2008) for a discussion of these steps.

2.4 Sustainability assessment frameworks

Fonseca *et al.* (2013*a*) defines a framework as a structure consisting of components framed together to support something. Sustainability assessment frameworks, used to support evaluation of sustainable development progress and reporting, therefore typically consist of a combination of components and may include indicators, conceptual models, criteria, goals, policies or other frameworks (Fonseca *et al.*, 2013*a*).

Two distinctive approaches can be followed when developing a sustainability assessment framework: a top-down (expert-driven) approach or a bottom-up (stakeholder-driven) approach. The top-down approach, also referred to as reductionist, typically makes use of quantitative indicators, developed or selected by industry experts and researchers according to clearly stated methodologies. In contrast, the bottom-up approach, also referred to as conversational or constructionist, typically makes use of qualitative indicators, developed or selected based on input from stakeholders and not explicitly according to any specific methodology. Top-down approaches are therefore typically scientifically rigorous but may fail to engage stakeholders, while the opposite is often true for the bottom-up approach (Fonseca *et al.*, 2013*a*; Waas *et al.*, 2014).

There is a large number of sustainability assessment frameworks that can be used to evaluate sustainable development progress (Singh *et al.*, 2009) and several publications present an overview of these frameworks. Singh *et al.* (2009) presents a comprehensive overview of sustainability assessment methodologies, including an overview of several indicator frameworks. Fonseca *et al.* (2013*a*) describes, compares and analyses five sustainability assessment and reporting frameworks relevant to the mining industry. As overviews of existing indicator frameworks can easily be found in literature, the subsequent sections aim to present only a very brief overview of some frameworks relevant to the present project. The reader is kindly referred to the above-mentioned sources for more detailed coverage of existing indicator frameworks.

The discussions in the subsequent sections are presented in order to form the foundation for discussions in Chapter 3 regarding the use of an existing indicator framework to form the basis of the framework developed in this study. Sections 2.4.1 to 2.4.6 present prominent international frameworks, followed by sections 2.4.7 and 2.4.8 that briefly introduces frameworks specifically relevant to the mining and metals sectors.

2.4.1 Global Reporting Initiative G4 Sustainability Reporting Guidelines

The Global Reporting Initiative (GRI) was launched in 1997 with the aim to enhance the quality, rigour and utility of sustainability reporting globally (Singh *et al.*, 2009) and to develop a common standard for sustainability reporting, similar to the international standards used for preparing financial statements of companies. As mentioned in Section 2.1, sustainability reporting has since, perhaps partially due to the availability of guidelines such as those by the GRI, gained significant traction in industry. The GRI guidelines have become a widely accepted standard with 78 per cent of companies surveyed worldwide and 82 per cent of the world's 250 largest companies referring to the GRI guidelines in their corporate responsibility reports in 2013 (KPMG, 2013).

The fourth update of the GRI's sustainability reporting guidelines – G4 – was published in May 2013. The G4 guidelines have a similar structure to previous versions and include reporting principles, standard disclosures and an implementation manual. The guidelines can be used by all organisations for preparation of any document aiming to disclose performance and impacts regarding the triple bottom line, regardless of the company's size, sector or location. The guidelines were developed in a process involving global stakeholders representing business, labour, civil society, financial markets, governmental agencies and regulators from several countries, as well as experts and auditors in various fields. In the G3 version of the guidelines, supplementary guidelines were provided for some sectors. In the G4 guidelines these sector supplements were replaced by Sector Disclosures, available for 10 different sectors, including amongst others, sector disclosures for the Mining and Metals sector. The sector disclosures should be "used in addition to and and not as a replacement of the G4 guidelines" (Global Reporting Initiative, 2013*c*). The mining and metals sector is specifically applicable to the present project. Figure 2.4 presents an overview of the structure of the G4 reporting guidelines, including notes of some sector specific content that was added to some universal aspects, as well as some additional sector specific aspects that were added to some categories in the sector disclosures for the mining and metals sector.

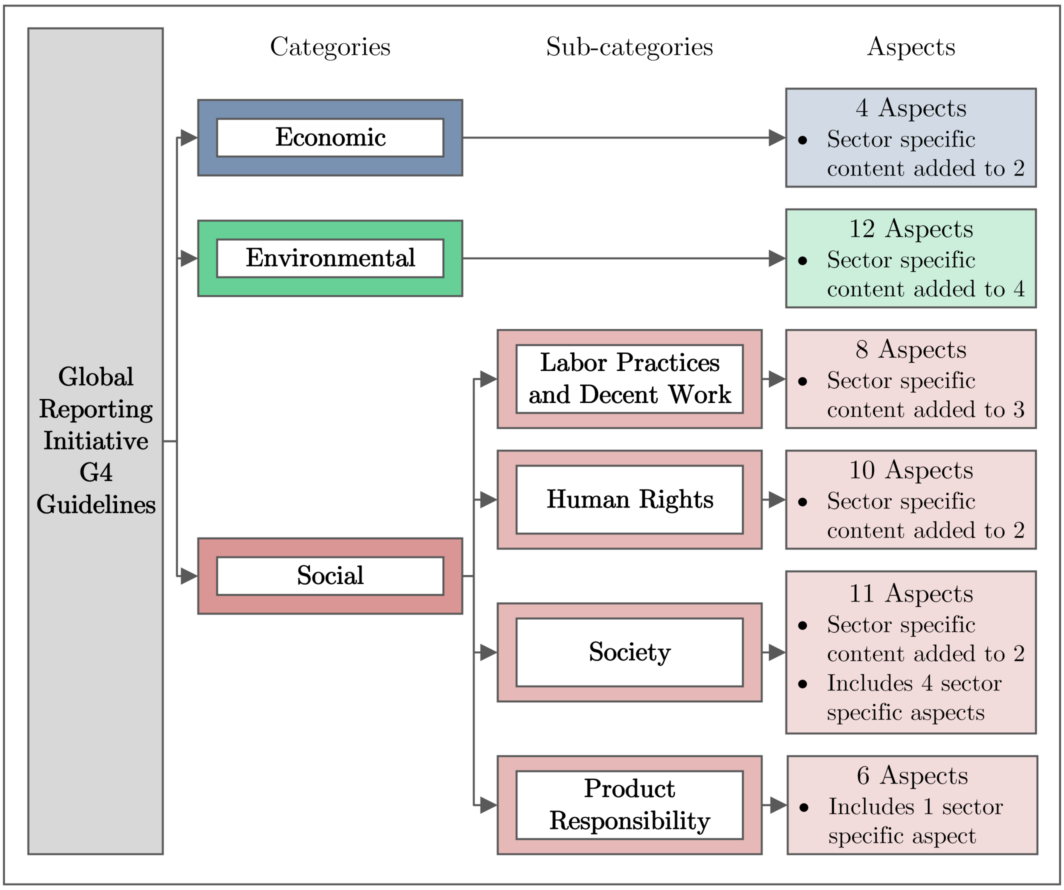


Figure 2.4: Overview of GRI G4 reporting guidelines for the mining and metals sector (Global Reporting Initiative, 2013*a*)

As can be seen in Figure 2.4, the GRI guidelines consider sustainable development progress in terms of economic, environmental and social performance and impacts, and the temporal orientation of the framework is retrospective – companies assess and report past year performance (Fonseca *et al.*, 2013*a*). Further, it is notable that the GRI G4 guidelines are very comprehensive, presenting 91 indicators (9 economic, 34 environmental and 48 social indicators) to evaluate the sustainability performance and impacts of an organisation. A notable oversight of the GRI G3 guidelines was the lack of geographical focus, but this was (at least partially) addressed in the G4 guidelines with a revision of the boundary protocol. The guidelines are organisationally-centred, similar to financial reporting frameworks (Fonseca *et al.*, 2013*a*), and therefore the information is presented in terms of the organisation and not specific operations within the organisation. However, in the G4 guidelines organisations are now also encouraged to specify the regions where specific organisation-linked impacts are applicable (Global Reporting Initiative, 2015).

Further, it is important to note that the GRI framework makes use of non-integrated indicators that are evaluated in isolation and does therefore not take synergies and interactions between the different dimensions of sustainability into account. Further, some authors have expressed their concern that the GRI approach to sustainability assessment and reporting may camouflage organisations' un-sustainability and may lead to flawed decision-making (Fonseca *et al.*, 2013*b*). In an evaluation of the GRI G3 guidelines according to the first four BellagioSTAMP principles[1], Fonseca *et al.* (2013*b*) noted that the GRI approach to sustainability reporting partially meets the principles and suggested some improvements. Notable improvements mentioned were the inclusion of integrated indicators, a prospective temporal orientation and a thorough disclosure of assumptions and uncertainties in reported data.

2.4.2 Sustainable Development Goals

The Sustainable Development Goals (SDGs), succeeding the Millenium Development Goals (MDGs), was adopted at the United Nations Sustainable Development Summit in September 2015. The SDGs define global sustainable development priorities and aspirations for 2030 and calls for action among governments, business and civil society, in developed and developing countries alike. Regarding implementation of the SDGs, governments are expected to take initiative and develop national policies and action plans reflective of the capacities and realities of the specific country. In contrast to the MDGs, the SDGs also explicitly call for action from businesses and stresses the importance of collaboration between all actors in order to successfully translate the goals to global reality (Global Reporting Initiative *et al.*, 2015). Figure 2.5 presents a brief overview of the SDGs, which consist of 17 goals that translate to 169 targets.

Following the adoption of the SDGs, the GRI, United Nations Global Compact (UNGC) and the World Business Council for Sustainable Development (WBCSD) published a document titled 'SDG Compass: The guide for business action on the SDGs'. This document aims to provide guidance to businesses on how to align their strategies with the SDGs, and how to measure and manage their contribution in terms of the SDGs. The developers of the SDG Compass also developed a large inventory of sustainability indicators gathered from several sources, most prominently the GRI G4 guidelines. Businesses are encouraged to map their value chains (noting that business impacts on the SDGs may be beyond the scope of assets owned or controlled by the business itself) in order to identify high impact areas and subsequently select or develop some indicators to track business performance in these high impact areas (Global

[1]Eight principles developed by sustainability assessment experts from across the globe that can be used to effectively design and evaluate existing sustainability assessment frameworks (IISD and OECD, 2009).

Figure 2.5: Overview of the Sustainable Development Goals (Global Reporting Initiative *et al.* (2015))

Reporting Initiative *et al.*, 2015).

As noted above, the SDGs define global sustainable development priorities and aspirations, but business-level action is also explicitly called for. The spatial application of the SDGs can therefore range from global to organisational level. Further, the SDG Compass states that companies should aim to "choose a combination of indicators that offer a balanced and adequate reflection of the company's performance and impacts in a given area." This entails, amongst others, a balance between indicators that measure outcomes and impacts (so-called lagging indicators) and those that predict outcomes and impacts (so-called leading indicators) (Global Reporting Initiative *et al.*, 2015). Regarding temporal orientation, the SDG Compass therefore encourage a balance between retrospective and prospective sustainability performance assessment.

2.4.3 CDP environmental disclosure system

CDP, formerly the Carbon Disclosure Project, is an international non-profit organisation that provides a global environmental disclosure system. CDP works with investors, companies, cities and governmental policymakers and aims to promote sustainable business culture worldwide by enhancing measurement, disclosure and management of organisational environmental information. CDP annually send standardised climate change, water and forest information requests to specific companies on behalf of more than 800 institutional investors CDP works with. Response to the information requests sent out by CDP is completely voluntary, but companies are encouraged to respond as disclosure of the requested environmental information proves the company's environmental commitment and progress to investors. Further, companies from which data was not requested are also allowed to disclose their environmental information via the CDP disclosure system (CDP, 2016).

The Climate Disclosure Standards Board (CDSB) is a special project of CDP and aims to promote the integration of climate change information into organisations' financial reporting (CDP, 2016). The CDSB offers a framework for reporting environmental information as part of the mainstream corporate annual report, thereby providing investors with information on the management of natural capital alongside information on the management of financial capital related to the organisation (Climate Disclosure Standards Board, 2015).

The CDP information requests, whether relating to climate change, water or forest, are all fairly well balanced in terms of retrospective reporting (for example past year emissions and water consumption) and prospective reporting (for example targets, implications, risks and opportunities). Although CDP has gathered "the largest global collection of self-reported environmental information" (CDP, 2016), this information is limited to only the environmental aspects of organisations, and the utility thereof is therefore limited.

2.4.4 International Integrated Reporting Council Integrated Reporting Framework

Integrated reporting, where the connectivity of information and the different capitals within an organisation is taken into account and reported in a single communication, is expected to become the global norm for annual reporting. This is a result of the increasing realisation of the importance of integrated thinking[2] and that the focus should be on value creation in the short-, medium- and long terms. It is based on this realisation that the Integrated Reporting (<IR>) Framework was developed by The International Integrated Reporting Council (IIRC). The <IR> Framework aims to improve the quality, cohesion, reporting efficiency and accountability of corporate reporting, as well as supporting integrated thinking and decision making focused on sustainable value creation (International Integrated Reporting Council, 2013).

The <IR> Framework defines six different capitals that an organisation influences in its process of value creation: financial, manufactured, intellectual, social and relationship, human, and natural capital. The <IR> Framework also presents eight fundamentally linked Content Elements that have to be in-

[2] "Integrated thinking is the active consideration by an organisation of the relationships between its various operating and functional units and the capitals that the organisation uses or affects." (International Integrated Reporting Council, 2013).

cluded in an integrated report. The eight Content Elements are described by eight questions; each question corresponding to a Content Element. The Content Elements were developed with the aim to capture a complete picture of the dynamic and systemic interactions of the organisation's activities as a whole. The elements therefore include a wide range of information ranging from an overview of the organisation and its external environment, to the risks and opportunities regarding sustainable value creation, to past year performance and future outlooks (International Integrated Reporting Council, 2013). The Content Elements therefore includes both retrospective and prospective information.

In order to remain flexible and accommodate the large number of different individual circumstances of different organisations, the <IR> Framework does not prescribe the use of specific indicators. It is therefore up to the organisation-specific knowledge and discretion of the person(s) preparing the integrated report as to which indicators will be used to accurately capture the required information (International Integrated Reporting Council, 2013).

2.4.5 Sustainability Accounting Standards Board

The Sustainability Accounting Standards Board (SASB) is an independent, non-profit organisation that develops industry-specific standards for the disclosure of material sustainability information. The SASB, based in the U.S.A., develops and maintains standards for 79 industries in 10 sectors, with the aim to improve the effectiveness of sustainability information disclosures. The SASB standards focuses on disclosure of information that is material, useful in decision-making and likely to influence the financial position or performance of the organisation or the entire industry. As a result, the SASB standards make use of an average of only 5 topics and 14 metrics per industry. By limiting the number of metrics to be disclosed, the SASB attempts to provide a sufficient, yet cost effective alternative to laborious sustainability surveys and questionnaires (Sustainability Accounting Standards Board, 2016). Recent research by Khan *et al.* (2015) has found strong supporting evidence for this approach, suggesting that superior results can be attained by focusing on a few material sustainability risks and opportunities.

The SASB standards comprise disclosure topics and accounting metrics. The SASB considers a comprehensive list of sustainability issues from which relevant, industry-specific disclosure topics are selected based on materiality research by the SASB. The universe of sustainability issues considered by the SASB comprises issues relating to environment, social capital, human capital, the business model and innovation as well as leadership and governance. Guidelines are provided detailing the steps to be followed when making use of SASB standards. These steps include a materiality assessment in which the user of the standards select appropriate disclosure topics (for the user organisation) from the disclosure topics listed as relevant for the industry under consideration. Industry-specific, predominantly retrospective, metrics measuring each topic are also provided. Further, the SASB standards highlight some important implementation and disclosure considerations.

2.4.6 United Nations Global Compact Communication on Progress

The United Nations Global Compact, established in 2000, is both a policy platform and a practical framework for companies that aim to conduct business in a sustainable and responsible way. The UNGC seeks to catalyse action in global business in order to align global business strategies and operations with ten universal principles on human rights (2 principles), labour (4 principles), environment (3 principles) and anti-corruption (1 principle) (United Nations Global Compact, 2016*a*). These ten principles form the foundation of action for any company seeking to advance the Sustainable Development Goals (SDGs). The UNGC, with more than 8400 companies from 162 countries participating at the time of writing, is the largest corporate sustainability initiative worldwide (United Nations Global Compact, 2016*b*).

Corporate participants in the UNGC make a commitment to integrate the ten universal principles in their business strategies and operations, and to continually endeavour to improve implementation of these principles. Progress in the implementation of these principles is reported in an annual Communication of Progress (COP) and organisations are rated as GC learner, GC active or GC advanced based implementation progress and the degree to which implementation progress is disclosed in the report. Although COPs are available to be viewed and downloaded on the UNGC website, participants are also encouraged to communicate their progress directly to their stakeholders by other means such as the company website and annual sustainability reports (United Nations Global Compact, 2012).

A basic COP template, as well as guidelines, are available to aid and guide participants such that their reports meet the COP requirements. The requirements regarding the information to be disclosed in the COPs are generally lenient and do not require quantitative measures of progress and targets. As a result, much of the information, whether it is retrospective information regarding progress or prospective information regarding targets and goals, is often qualitative and not directly measurable. Further, the ten principles that are to be addressed in the COP are not comprehensive. The UNGC therefore encourages participants seeking to disclose their sustainability progress more comprehensively to make use of the GRI reporting framework in the preparation of their COPs. Global Reporting Initiative and United Nations Global Compact (2013), for example, provides details on how the GRI reporting framework and the UNGC COP can be used to complement each other.

2.4.7 Azapagic's framework for sustainable development indicators for the mining and minerals industry

Adisa Azapagic, an environmental engineer, developed a framework for sustainable development indicators specifically relating to the mining and minerals industry in 2003 (Azapagic, 2004). This framework, cited in nearly 500 articles on Google Scholar at the time of this writing, is "one of the most influential in mining-related research" according to Fonseca *et al.* (2013*a*).

The framework proposed by Azapagic (2004) is based on the GRI G2 guidelines. At that time, the GRI had not yet published sector specific guidelines and the framework developed by Azapagic therefore contributed to the development of indicators that are specifically applicable to the minerals and metals industry. Similar to the GRI framework, Azapagic's framework has a retrospective temporal orientation and is organisationally-centred (and therefore also lacks specific geographical focus). The framework developed by Azapagic is not widely used, perhaps because it is based on the now-outdated GRI G2 guidelines (Fonseca *et al.*, 2013*a*). However, Azapagic's framework includes several integrated indicators that attempt to improve the extent to which sustainability is assessed as an holistic concept by considering all its dimensions simultaneously (Azapagic, 2004). Fonseca *et al.* (2013*a*) contests the value of the integrated indicators proposed by Azapagic (2004) by stating that the indicators "do not seem to offer a thorough understanding of the potential trade-offs and synergies among the many sustainability dimensions affected by mining operations". The reasons for this statement are not discussed however.

2.4.8 Seven questions of sustainability

The Mining, Minerals and Sustainable Development (MMSD) project was undertaken by the International Institute for Environment and Development (IIED) to review global mining- and mineral-related practices, with the aim of ultimately improving the sustainability of the mining and minerals industry. MMSD Global created several regional partners, operating in Southern Africa, South America, Australia and North America. As part of its work, MMSD North America aimed to develop an approach to assess whether the contribution of a specific mining or mineral project to the three dimensions of sustainability over its entire life cycle is positive or not. In order to guide such an assessment, a framework was designed (MMSD, 2002).

The framework consisted of seven components each articulated as a question which, when answered, gives an indication of whether the net contribution of the project or operation to sustainability, over the long term, will be positive or negative. Figure 2.6 presents the seven questions corresponding to the seven components. An ideal answer and a hierarchy of objectives, indicators and specific measurements is suggested for each question and these can be tailored to the specific conditions of the case being considered (MMSD, 2002).

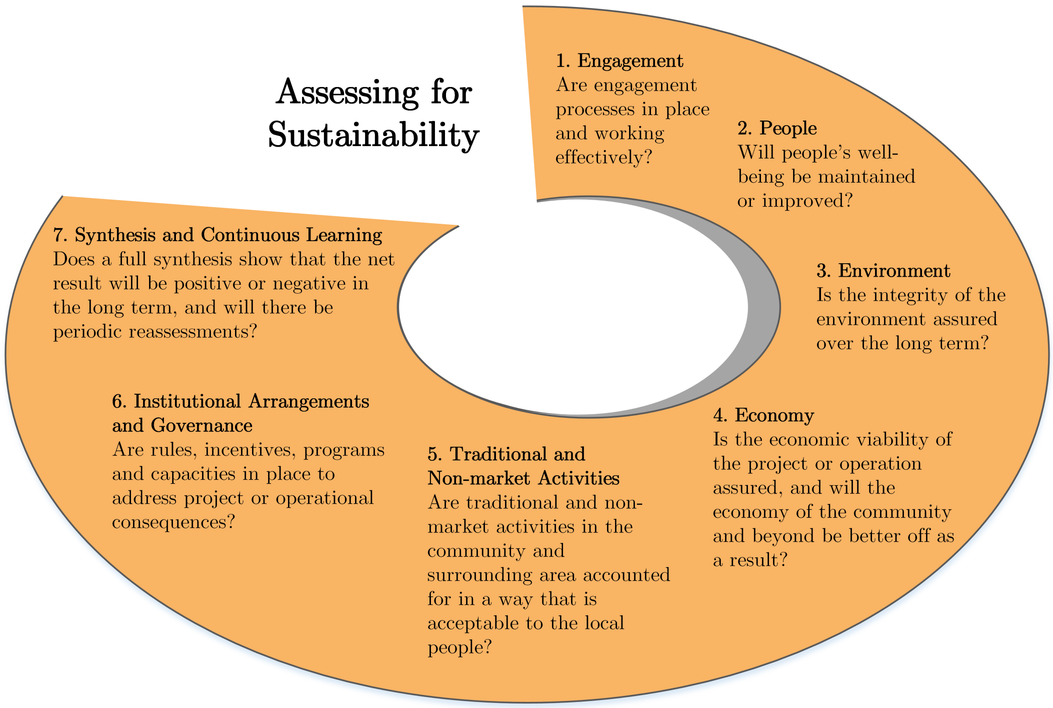


Figure 2.6: Overview of the MMSD seven questions approach to assessing sustainability for mining and minerals activities (adapted from MMSD (2002))

It is important to note that assessment using this framework aims to identify the important considerations that should form part of the decision-making process as a company aims to progress towards sustainability. The use of this framework does not give any guidance on the decision-making process itself or the inevitable trade-offs that will have to be considered (MMSD, 2002).

This framework is more conceptual than practical, in contrast to, for example, the GRI guidelines discussed in Section 2.4.1. However, it has the advantage that it assumes a prospective temporal orientation, considering the anticipated impacts of a project over its entire life cycle. Further, this framework also encourages analysis of the trade-offs and synergies between its different dimensions through the last question: "Does a full synthesis show that the net result will be positive or negative in the long term, and will there be periodic reassessments?". However, no guidance is provided as to how such integrated assessment should be done (Fonseca *et al.*, 2013*a*; MMSD, 2002).

2.5 Chapter 2: Conclusion

This chapter explored the meaning of sustainable development and sustainability, and it was stressed that sustainable development is a holistic concept with all three its dimensions – economic, environmental and social – equally important in achieving a state of sustainability. Further, measurement of sustainability with the use of indicators, the usefulness of aggregating these indicators and different aggregation methods were discussed. Finally, the reader was introduced to some of the most prominent sustainability reporting frameworks that exist. The concepts, methods and frameworks discussed in this chapter form the foundation of the framework developed in this project, as discussed in the next chapter.

Chapter 3

Development of the framework

The primary objective of this project was to develop a framework that facilitates the comparison of potential metal beneficiation development opportunities. Such a framework has to rigorously and transparently quantify the potential value capture by potential industries that can be developed in South Africa. Chapter 2 introduced the concepts of sustainable development, sustainability indicators, aggregation of indicators and existing indicator frameworks to serve as foundation for the development of the framework. Based on this knowledge, the aforementioned framework of sustainability indicators was developed.

This chapter therefore aims to present detail on the intended purpose and scope of the framework (Section 3.1), the structure of the framework (Section 3.2) and the methodology used for its development (Section 3.3).

3.1 Purpose and scope

It is appropriate to start this section by briefly elucidating the meaning of 'framework' in the context of this investigation. At the start of Section 2.4 it was noted that a framework can generically be defined as a structure consisting of components framed together to support something (Fonseca *et al.*, 2013*a*). In the present investigation, the developed framework is composed of selected sustainability indicators that measure most of the important value capture aspects of a specific development opportunity. The performances of different development opportunities in terms of these aspects are compared and the outcomes of the comparison are presented in an easy-to-use format. This framework therefore fits the definition by Fonseca *et al.* (2013*a*): it consists of components (indicators) that are structured in a specific way to facilitate the comparison of development opportunities and thereby produce results that can support decision-making by policymakers.

With the meaning of 'framework' now defined, the exact purpose of the framework can be defined. The purpose of this framework is to facilitate the high level, typically scoping phase comparison of different metal beneficiation industries that can be established in a country where such industries are lacking. Such comparison allows policymakers to rapidly determine which opportunities are likely superior to others in terms of producing sustainable positive outcomes and therefore warrant the investment of resources required to complete more detailed feasibility assessments. To this end, the framework serves as an assessment tool that reduces the many complex aspects influencing the feasibility of establishing a new industry to a palatable number of aggregated indicators that ultimately facilitate easy, objective and rapid comparison of opportunities. It is important to note that the aim of the framework is not to serve as a perfectly comprehensive, -holistic and -objective tool. The framework aims to find an acceptable trade-off between being a perfectly comprehensive, -holistic and -objective tool, which is difficult to use and interpret, and an easy-to-use tool that simplifies the aspects being considered to a point where it is reduced to nothing more than scientifically meaningless numbers.

Due to the similarities between different beneficiation industries, the framework was developed generically, such that it can be applied to beneficiation industries for any metal. Thus, when making use of the framework, it is largely up to the knowledge and discretion of the person making the comparison as to what aspects included in the framework might be insignificant or unimportant for its present use and can therefore be neglected without compromising the accuracy of the results. Similarly, some important industry-specific aspects of some industries might not be taken into account in the framework and these aspects should then either be included in the framework in an appropriate manner or brought into consideration when assessing the framework results. It is of great importance that the person making use of the framework takes note of the considerable potential for subjectivity and prevent personal bias from influencing the results by carefully considering the consequences of any changes made to the framework.

Further, it should be noted that the framework was developed for industry-level assessment and therefore neglects several aspects that were deemed too variable between different organisations in an industry to allow for accurate and representative generalisation of the aspect for the entire industry. It is therefore once again stressed that the person employing this framework should have a good knowledge of the industry being considered as well as a sound understanding of the working of this framework, allowing due consideration of organisation-specific aspects during results analysis, if deemed necessary.

3.2 Framework structure

Figure 3.1 illustrates the comparison of potential development opportunities as facilitated by the framework. The framework has a symmetrical indicator structure composed of sub-indicators (forming the bottom framework level), which are combined to form indicators (forming the intermediate framework level), which are in turn aggregated to produce a single composite indicator, or index, for each dimension of sustainability (forming the top framework level). This allows the comparison of different potential industries at the hand of only three indices. In order to limit information loss and the subsequent increased inaccuracy, the three indices are not aggregated further to produce a single overarching composite indicator. It was deemed easy enough to intuitively compare the three indices that is calculated for each beneficiation opportunity.

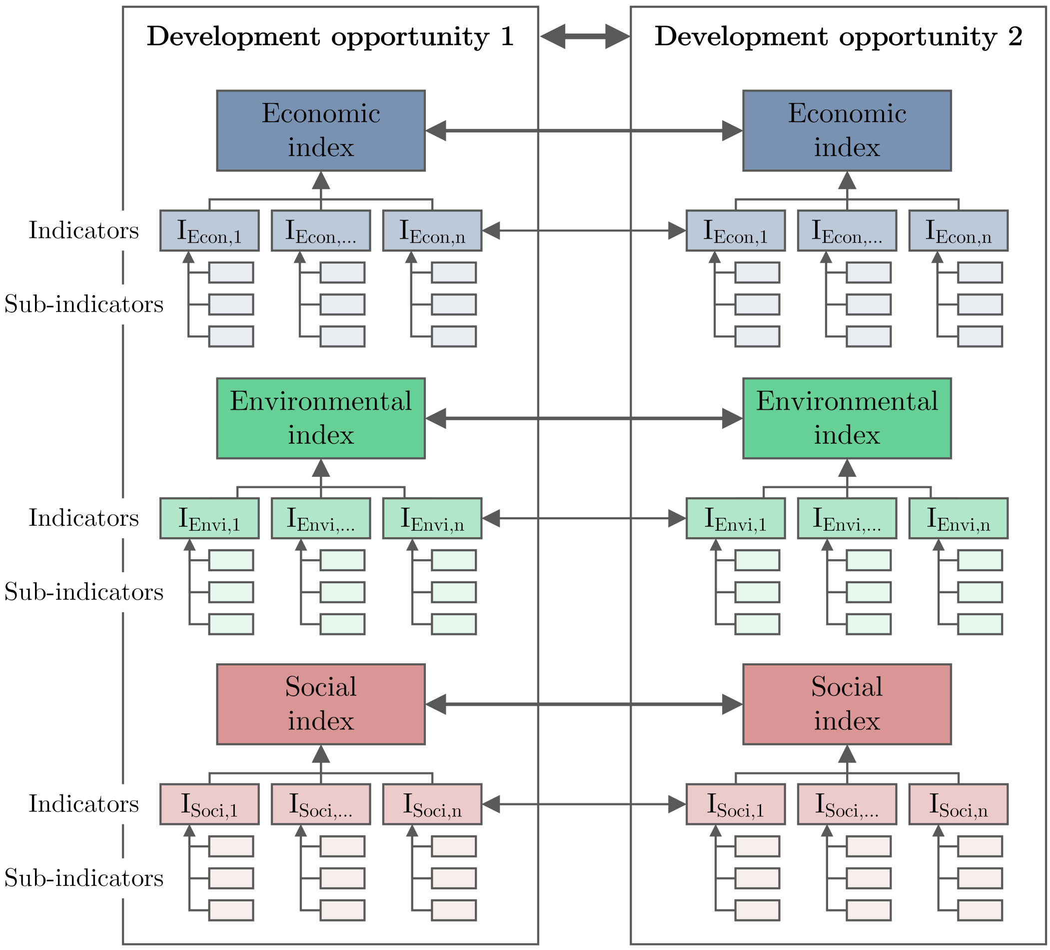


Figure 3.1: Framework structure facilitating comparison of potential development opportunities

The hierarchical structure of the framework allows the user to identify the individual underlying indicators or sub-indicators that contribute significantly to the relative superiority or inferiority of a specific development opportunity, ensuring transparency of results generated by use of the framework.

3.3 Framework development methodology

Based on the discussions above, this section now presents the methodology used to develop the framework, as well as some insight into the working of the framework itself based on its underlying structure. The rationale of decisions made in the construction of the framework regarding the basis of the framework, selection of indicators, defining indicator scope, judging indicator impact and grouping indicators, as well as the choice of weighting, normalisation and aggregation methods are discussed, as each of these decisions has a potentially significant impact on the results generated by the framework. The process of validating the indicator structure of the framework by consultation of experts and the subsequent alterations made is also discussed.

Figure 3.2 provides an overview of the methodology followed in the development of the framework. The methodology is roughly based on that proposed by OECD and European Commission (2008), as discussed in Section 2.3. Phase 1, the literature review, was presented in Chapter 2. This chapter presents phase 2, the development of the framework, and phase 3 is then presented in subsequent chapters. The phases correspond to the three sub-objectives of this project, as illustrated in Figure 1.1 in the introduction of this document.

As can be deducted from earlier descriptions of the purpose and aims of this project, this project is by nature exploratory. The research objectives and subsequently the research methodology are therefore structured to support the development of the framework and to test its utility by application so as to draw conclusions regarding the potential use of such a framework.

3.3.1 Basis of the framework

The framework developed in this project depends on the use of quantitative data to compare different development opportunities in an objective manner. As noted in the introduction to this project in Chapter 1, the increasing amount of sustainability information that is available in the public domain is seen as an opportunity and the rapid collection of this easily accessible data is therefore central to the utility of the framework. Using an existing reporting framework as basis for the present framework allows the user of the present framework to find organisations active in the relevant industries elsewhere in the world and use the data reported by these organisations (according to the

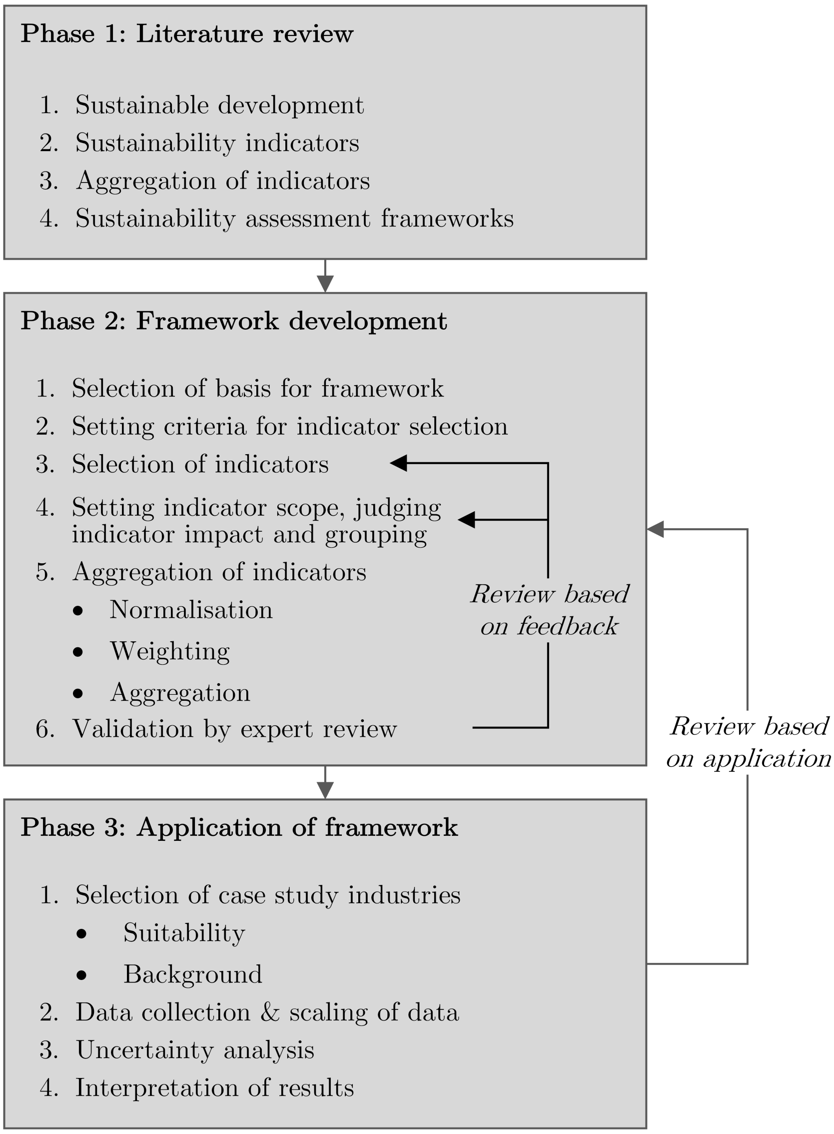


Figure 3.2: Overview of the methodology followed in the development of the framework

guidelines of the existing framework). This data can be used as a basis for the comparison of the potential of developing these industries in a target country. As such, basing the present framework on an existing reporting framework or guidelines has several advantages, apart from the obvious advantage of simplifying the process of developing or selecting suitable indicators:

1. Data is available and accessible;
2. Data is in the right form, thereby eliminating or reducing the need to adjust the data;

3. The transparency and accuracy, and therefore credibility, of data is already proven to be acceptable.

Therefore, a decision was made that the present framework will be based on one or more existing sustainability reporting frameworks or guidelines. However, many such reporting frameworks and guidelines are used internationally (as discussed in Section 2.4) and as a result criteria had to be set to identify the most appropriate framework(s) that can be used as basis for the present work. Du Plessis and Bam (Forthcoming) outline criteria that can be used to assess reporting frameworks and guidelines for this purpose. These criteria, as reported by Du Plessis and Bam (Forthcoming), are outlined below:

1. **Scope of indicators** (Importance: Required)
   It can only be concluded that a development opportunity is superior to another if both are considered in terms of all the aspects of sustainability. Therefore, the present framework must be based on a framework or set of guidelines that considers all the dimensions of sustainability.

2. **Data disclosure** (Importance: Required)
   Being able to analyse index values and identify the individual underlying indicators that contribute significantly to the relative superiority or inferiority of a development opportunity is a notable strength of the hierarchical structure of the present framework. Making use of disaggregated data that is only aggregated in the framework therefore plays a vital role in the utility of the framework and the transparency of the results it generates. As such, only frameworks that require the disclosure of disaggregated information can be used as a basis for the present framework.

3. **Temporal orientation** (Importance: Recommended)
   A framework that requires disclosure of prospective information (rather than retrospective) is favourable as this eliminates the need to adjust retrospective data for inter alia, exchange rate changes, changes in industry and growth factors in order to be used for prospective comparison of development opportunities. Such alterations typically increase the inaccuracy of data, although the increased inaccuracy may be acceptable if limited to a minimum as the framework is aimed at only high level comparison of development opportunities.

4. **Nature of indicators** (Importance: Recommended)
   Development opportunities have to be compared in terms of the same indicators for each opportunity. Although some frameworks, the IIRC <IR> Framework for example, do not prescribe specific indicators due to considerations regarding the quality of disclosed information, comparison of narrative-based or non-standardised indicator information is tedious

and problematic. As such, frameworks that make use of standardised indicators are favourable.

Further, it is widely accepted in literature that integrated indicators are required in order to account for the interrelationships between the different dimensions of sustainability (Azapagic, 2004; Hak *et al.*, 2012; Fonseca *et al.*, 2013*b*) and it is recommended that a balance between non-integrated and integrated indicators are found (Fonseca *et al.*, 2013*b*). As a result, frameworks that include integrated indicators are deemed favourable.

5. **Level of assessment** (Importance: Recommended)
As the present framework is developed for industry-level assessment and comparison of development opportunities, it is advantageous if the framework or guidelines on which it is based requires the disclosure of industry-level information. However, most sustainability reporting frameworks and guidelines are developed for organisation-level assessment of sustainability progress and such information can be scaled to represent an industry, although this may introduce some inaccuracy. As a result, this criterion is not considered to be paramount, but favourable.

6. **Usage** (Importance: Recommended)
Use of a reporting framework or guidelines by many organisations in many different industries, operating under different circumstances (political, economic, geographical etc.), increases the likelihood of finding information representative of the specific situation in the country one wishes to assess. Widespread use of a reporting framework or guidelines is therefore favourable in terms of the availability of appropriate data.

   Further, widespread use of a framework or guidelines implies that it is considered acceptable and sufficient by many users, which increases the credibility of information based on such a framework. It is, however, accepted that this is not always the case and that less widely used frameworks may also be appropriate in some cases. Widespread use of a framework or guidelines is therefore deemed favourable, but not a requirement.

Only recognised frameworks that include requirements to ensure disclosure of high quality information were considered to serve as a basis for the present framework. As such, the criteria above do not consider the quality of information disclosed when making use of a framework. Further, sector-specific frameworks were not considered to serve as a basis for the present framework as this framework aims to be applicable to any beneficiation industry and therefore needs to be based on a generic framework. The framework by Azapagic (2004) and the Seven questions of sustainability framework (MMSD, 2002) introduced in Chapter 2, both specifically developed for the metals and minerals industry, were therefore not considered to serve as the basis for the present framework. The SDGs and the subsequent SDG Compass, discussed in Chapter 2, include an inventory of many indicators gathered from several sources, including the GRI sustainability reporting guidelines, but do not explicitly provide a structure according to which indicators should be used to report specific aspects. Rather, organisations are encouraged to map their value chains in order to identify areas of high impact and then select or develop indicators to track progress in these areas (Global Reporting Initiative *et al.*, 2015). As such, the SDGs and SDG Compass were not considered suitable to serve as basis for the present framework. Table 3.1, on the following page, summarises the results of analysing the five remaining sustainability assessment frameworks introduced in Chapter 2 according to the above-mentioned criteria.

As noted by Du Plessis and Bam (Forthcoming), when studying Table 3.1 it can be observed that none of the assessed frameworks meet all the ideal criteria. This might be expected as the present project makes use of information from the frameworks in a different way than the purpose these frameworks were developed to serve. Although this does not necessarily disqualify the use of these frameworks, it does, importantly, imply that if these frameworks are used as a basis, some manipulation and scaling of data will be required, likely also requiring some assumptions to be made. This will inherently decrease the accuracy of the results generated by the framework (Du Plessis and Bam, Forthcoming).

Further, it can be observed that, based on the criteria evaluated here, the GRI G4 Sustainability Reporting Guidelines is the best suited framework to be used as basis for the present framework. The GRI G4 guidelines have both the required characteristics (comprehensive scope of indicators and full disclosure of disaggregated data) and additionally have two of the five recommended characteristics. The most prominent shortcoming of the GRI G4 guidelines for the present purpose is its lack of integrated indicators, for which it has also been criticized in literature (Fonseca *et al.*, 2013*b*).

The CDP environmental disclosure system also performs strongly based on the criteria evaluated here, having three ideal characteristics and one acceptable characteristic. However, it has the critical shortcoming of only considering environmental aspects and not any economic or social aspects. As a result, it would not be possible to use the CDP environmental disclosure system as the sole source of information and the CDP disclosures would therefore have to be used complementary to another framework which includes economic and social disclosures. Although the CDP disclosure system also has shortcomings similar to the G4 guidelines in terms of using non-integrated indicators and organisation-level disclosure, it has the advantage of including some prospec-

Table 3.1: Summary of characteristics of several prominent international sustainability reporting frameworks (as in Du Plessis and Bam (Forthcoming))

	GRI G4 Sustainability Reporting Guidelines	**CDP environmental disclosure system**	**IIRC Integrated Reporting Framework**	**Sustainability Accounting Standards Board**	**UNGC Communication on Progress**
Scope of indicators[a]	Comprehensive	Limited	Variable	Limited	Limited
Data disclosure[a]	Open access	Open access	Open access	Open access	Open access
Temporal orientation[b]	Predominantly retrospective	Retrospective & Prospective	Retrospective & Prospective	Predominantly retrospective	Retrospective & Prospective
Nature of indicators[b]	Standardised	Standardised	Non-standardised	Standardised	Standardised
	Non-integrated	Non-integrated	Integrated	Non-integrated	Non-integrated
Level of assessment[b]	Organisation level	Organisation level	Organisation level	Organisation level	Organisation level
Usage[b]	Almost universal	Widespread	Increasingly widespread	Increasingly widespread	Limited

Key:	[a] Required	[b] Recommended	Ideal	Acceptable	Poor

tive indicators, rather than only retrospective ones as is the case with the G4 guidelines.

The IIRC <IR> Framework has two ideal and three acceptable characteristics, making it very suitable to be used as a basis for the present framework. The IIRC <IR> Framework, however, has the shortcoming that it does not specify the indicators that are to be used to report specific aspects and it is therefore inevitable that different organisations will use different indicators to report a specific aspect. This makes comparison of the information difficult, likely requiring manipulation of the information which, again, introduces inaccuracy in the results generated from that information. Further, 'materiality' is one of the guiding principles of the IIRC <IR> Framework and this encourages organisations to primarily disclose information "...about matters that substantively affect the organisation's ability to create value over the short, medium and long term" (International Integrated Reporting Council, 2013). As a result, the scope of disclosures can vary, further complicating the comparison of information from different organisations. However, the IIRC <IR> Framework does emphasise the importance of integrated thinking; an aspect that is sorely missed in the GRI G4 guidelines. Ultimately, taking all these factors into consideration, the current widespread use and ease-of-use of the GRI G4 guidelines still makes it preferable to the IIRC <IR> Framework as a basis for the present framework. However, as noted by Du Plessis and Bam (Forthcoming), the increasing use of the IIRC <IR> Framework expected globally may soon make the IIRC <IR> Framework preferable to the GRI guidelines for this purpose.

Finally, as apparent in Table 3.1, the Sustainability Accounting Standards Board standards and the United Nations Global Compact Communication on Progress framework are less well suited to serve as a basis for the present framework. Both these guidelines require a limited number of predominantly non-integrated disclosures at organisation-level. Neither of these guidelines are very widely used, although the SASB standards are making progress in this regard. Therefore, based on the criteria considered here, these guidelines are less suitable to serve as a basis for the present framework than the GRI G4 guidelines.

3.3.2 Selection of indicators

Having decided that the GRI G4 Sustainability Reporting Guidelines will serve as basis for the present framework, indicators to be used in the framework had to be selected. This section describes the process followed in this regard.

As a result of the nature of the present framework, there are two specific requirements that have to be met by indicators to be of use in the present framework, namely:

1. Each indicator has to be generalisable for an entire industry;
2. Each indicator has to be applicable to an industry that is yet to be established.

Further, in the development of the present framework it was considered important that the framework is comprehensive and objective enough to produce dependable results, but remains easy to use and produces easily interpretable results. As such, limiting the number of indicators measuring each aspect was desirable and consequently this was treated as an additional consideration in the selection of indicators. Limiting the number of indicators measuring an aspect also prevents double-counting of the impact of that aspect, although double-counting can also be addressed by altering indicator weights.

As mentioned in Chapter 2, the G4 guidelines makes use of 91 indicators, consisting of 9 economic, 34 environmental and 48 social indicators. The mining and metals sector disclosures present a number of additional inclusions and indicators relevant to the mining and metals sector. By application of the above-mentioned criteria to the G4 guidelines, numerous indicators unsuitable for use in the present framework were identified and as a result the number of indicators was reduced from 91 to 37.

Based on the first criterion, many indicators in the G4 guidelines measuring sustainability aspects related to organisation-specific circumstances, -policy and/or -management philosophy were excluded as such aspects cannot be generalised accurately for an entire industry. For example, indicators measuring the ratio between the wages of different employee groups, or the influence of operations on specific natural habitats or water sources are bound to differ substantially based on organisation-specific policies or the location of operations. Such indicators can therefore not be generalised with acceptable certainty. Considering the second criterion, several indicators measuring progress in a retrospective manner that is not suitable to be applied in a prospective manner (as would be required when considering an industry that is yet to be established) were excluded. These indicators were mostly those aimed at assessing sustainable development progress over consecutive years in an organisation, for example reductions in energy use or reductions in greenhouse gas emissions over the past year period. Such indicators are not applicable in the present framework.

A further five indicators were removed in accordance with the aforementioned objective of limiting the number of indicators addressing each aspect and preventing over-emphasising the impact of some aspects in the framework.

The indicators excluded under this criterion typically presented information already captured in other indicators in the G4 guidelines in a different manner so as to present a clearer picture of the actual sustainable development progress of an organisation. Indicators presenting the energy intensity or greenhouse gas emissions intensity, for example, only presents information already captured by other indicators (measuring energy consumption and the mass of greenhouse gas emissions) in ratio form. The information presented by these ratios undoubtedly aids the user in gaining a clear picture of the actual sustainable development situation of an organisation and is especially useful in comparing the efficiency of organisations of different sizes operating within the same industry. However, with the focus of the present framework being on rapid, high level assessment, these indicators were deemed excessive. Further, the absolute magnitudes of impacts were deemed more important in the comparison of different potential industries than their relative intensity or efficiency. In the comparison of potential industries, a large negative impact cannot be considered acceptable if it is accompanied by a large positive impact (linking strongly to the rejection of compensability in the aggregation process, as discussed in Section 3.3.6, below). As such, two indicators measuring such ratios were not included in the framework. A further three indicators were excluded because they measure impacts already sufficiently quantified by other indicators. Thus, after all these exclusions, 32 of the original 91 indicators were left, consisting of 6 economic, 12 environmental and 14 social indicators. These were the preliminary indicators included in the framework. Figure 3.4 provides a summary of the preliminary indicators that were included in the framework, as well as the grouping and impact of the indicators (discussed in the next section). The preliminary indicators included in the framework were later adjusted based on the feedback received in the validation process (discussed in Section 3.3.7).

Section A.5 in Appendix A presents a complete list of indicators excluded from the present framework by application of the above-mentioned criteria and considerations, as well as a short explanation of the reasons for each indicator's exclusion.

3.3.3 Indicator scope, grouping and judgement of impact

The present framework is aimed at prospective assessment of development opportunities at industry-level, and the GRI Sustainability Reporting Guidelines indicators used in the framework were originally developed for retrospective sustainability reporting at organisation-level. As such, the scope statements of the indicators had to be revised. Although the essence of all the indicators remained the same, the exact inclusions were tailored to allow generalisation of the indicators to represent information for a newly established industry, as opposed to representing retrospective information of only one organisation. For example, the GRI G4 scope of indicator G4-EN8 (Water withdrawals by source) includes disclosure of the sources from which water is withdrawn, however, in the present framework the scope of this indicator was revised to exclude consideration of the sources from which water is withdrawn as these will vary for different organisations within an industry.

Further, as the present framework makes use of quantitative comparison of development opportunities in terms of different indicators, indicators designed to present qualitative information in the GRI G4 guidelines had to be revised such that this qualitative information is quantifiable and therefore comparable for different development opportunities. In the present framework, risk and impact scores are used to quantify indicators that measure predominantly qualitative aspects. This quantification in terms of risk and impact scores was accomplished by making use of a quantification matrix, as illustrated in Figure 3.3. In Figure 3.3 the vertical axis captures the perceived severity of the potential impact, while the horizontal axis captures the perceived likelihood or relevance of that impact actually occurring (where 1 is the minimum and 5 is the maximum for both axes). Combination of the perceived potential impact and the likelihood of that impact occurring determines the risk or impact score associated with that case. If, for example, the potential impact is considered severe and rated 4 out of 5, but the likelihood of that impact occurring is low, say 2 out of 5, the overall risk score is 5. However, if the likelihood of that

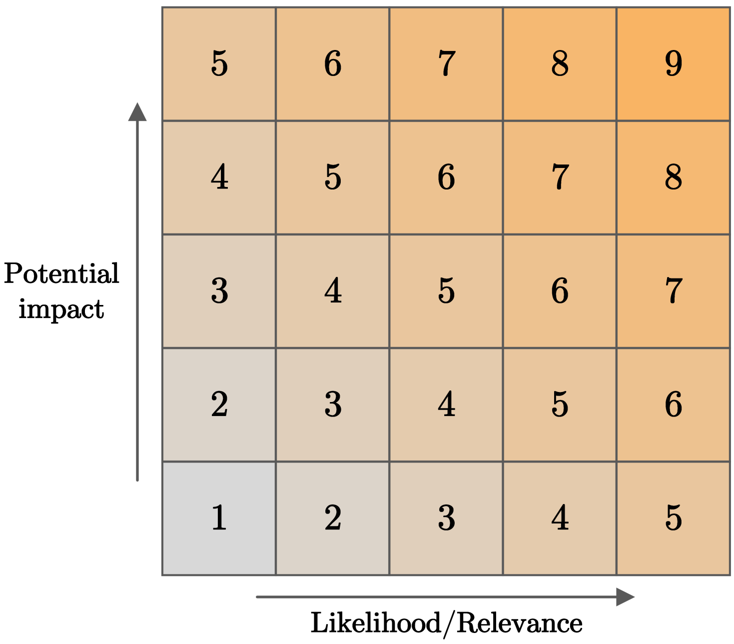


Figure 3.3: The quantification matrix used to quantify perceived risk or impact

impact occurring is also high, say 4 out of 5, the overall risk score is 7.

Upon revision of the scope of the indicators, considering the importance of ease-of-use for the present framework, it was deemed desirable to define the scope of the indicators such that a high level assessment can be done with limited inclusions or a more detailed assessment can be done where the scope of the indicators is more comprehensive. The revised scope statements for all the indicators used in the present framework are presented in Appendix A. Table 3.2, on the next page, presents an example of these scope statements for indicators and sub-indicators as provided in Appendix A. The respective inclusions for a high level assessment and a more detailed assessment (written in *italics*) are provided, as well as the details of the units of measure, aspect measured and the SDGs addressed by each indicator or sub-indicator. For indicators, the sub-indicators of which the indicator is composed are listed, while for sub-indicators the underlying GRI G4 indicators from which the sub-indicator is derived (where applicable) are also listed.

Sub-indicators measuring similar aspects have to be grouped together in order to make the process of allocating weights, discussed in Section 3.3.5, accurate. This helps prevent over-emphasising some aspects that are measured by several indicators compared to aspects measured by fewer indicators. The GRI Reporting Guidelines already group indicators according to the aspect each measures, however, after revision of the scope of all the indicators to be included in the framework, the grouping of some of the indicators was adjusted slightly to ensure a logical framework structure.

Finally, the impact of each indicator was established as this influences the normalisation and aggregation processes in the framework (discussed further in sections 3.3.4 and 3.3.6, below). For example, the impact of generating higher financial earnings is positive, while the impact of producing higher greenhouse gas emissions is clearly negative. Figure 3.4 provides a summary of the grouping and impact of the preliminary indicators that formed part of the framework at this point. Table 3.4 at the end of this chapter presents a complete summary of the grouping, impact and weighting of the final indicators included in the framework.

3.3.4 Normalisation

Section 2.3.2 introduced the concept of normalisation and how it allows the aggregation of data values measured in different units of measure when making use of some aggregation methods. The incompatibilities between some normalisation, weighting and aggregation methods were also outlined.

Table 3.2: An example of scope statements for arbitrary (a) economic, (b) environmental and (c) social indicators and sub-indicators as presented in Appendix A

(a) Economic indicator

Indicator ID	*Composed of*	*Indicator Name*	
Econ-5	**Econ-5.1** **Econ-5.2** **Econ-5.3** **Econ-5.4**	**Competitiveness**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

This indicator quantitatively captures four strategic factors that may influence the potential success of an industry in a given competitive socio-economic environment. These factors are based on Porter's Diamond of National Advantage and include factor conditions, demand conditions, related & supporting industries and rivalry (Porter, 1990). These factors are quantified in the form of impact scores captured by sub-indicators Econ-5.1 through Econ-5.4.

(b) Environmental sub-indicator

Indicator ID	*Derived from*	*Indicator Name*	
Envi-1.1	**G4-EN1**	**Materials by weight**	
		Measured by:	Mass of material
		Measured aspect:	Materials
		Relevant SDGs:	8,12

Scope:

Identify the organization's primary products and services. Identify the mass of total materials used. The material usage should, as a minimum, include:

- Raw materials (that is, natural resources used for conversion to products or services such as ores, minerals, wood)
- Associated process materials (that is, materials that are needed for the manufacturing process but are not part of the final product, such as lubricants for manufacturing machinery)
- Semi-manufactured goods or parts, including all forms of materials and components other than raw materials that are part of the final product
- Materials for packaging purposes, which include paper, cardboard and plastics

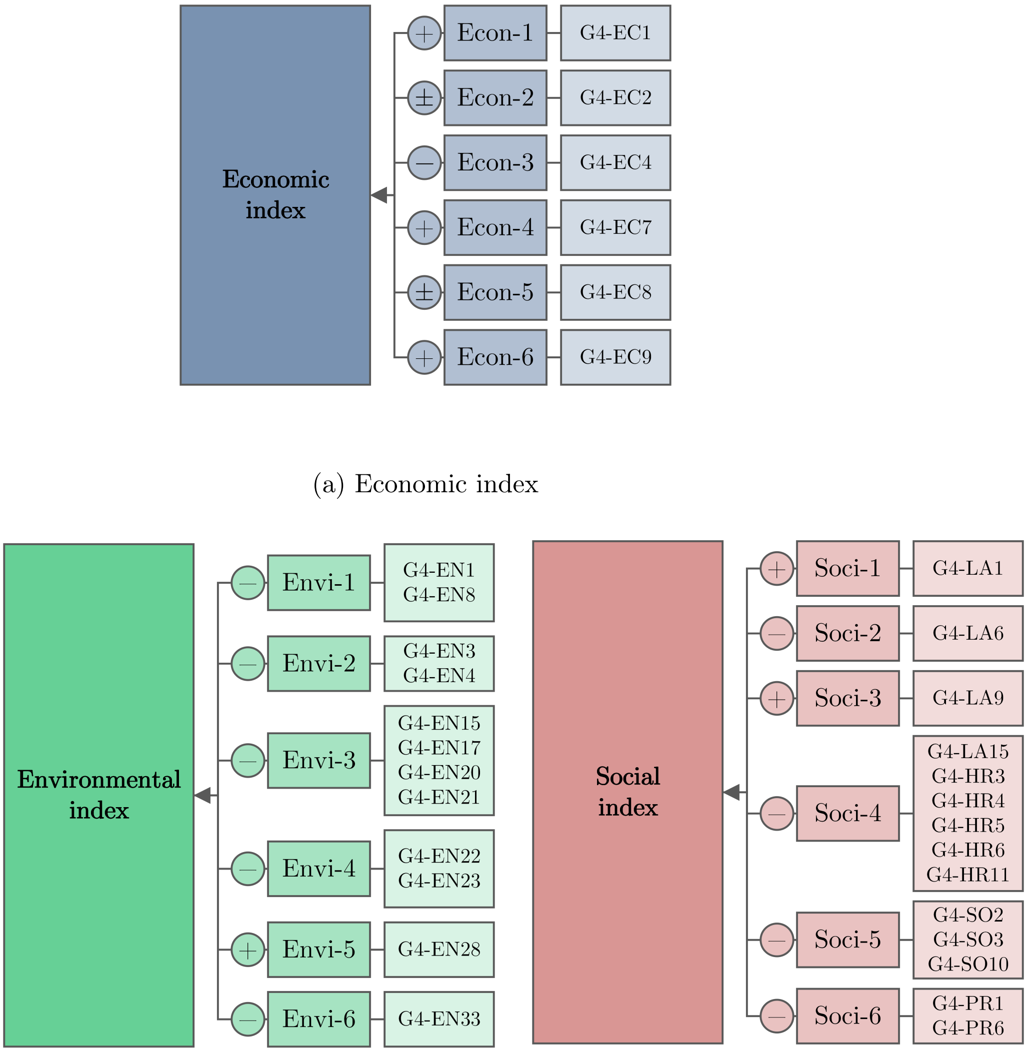
For detailed assessment, material derived from renewable and non-renewable sources can be reported as two separate indicators, thereby allowing different weights to be allocated to the indicators (if, for example, material use from renewables is deemed more desirable than use of non-renewable materials).

(c) Social sub-indicator

Indicator ID	*Derived from*	*Indicator Name*	
Soci-1.1	**G4-LA1**	**Number and rate of new employee hires**	
		Measured by:	Number of employees
		Measured aspect:	Employment
		Relevant SDGs:	5,8

Scope:

This indicator aims to capture the total expected new employment that will be created by development of the industry under consideration. This indicator therefore includes all expected permanently employed personnel as well as independent contractors that is necessary for the day-to-day operation of the industry. Temporary project personnel, such as construction personnel, are not included.
For detailed assessment, the total expected employment can be split into separate indicators according to age and gender. Reporting separate indicators allows different weights to be allocated to the indicators, which may be sensible if employment in different categories are deemed to have different levels of desirability.



(a) Economic index

(b) Environmental index

(c) Social index

Figure 3.4: Grouping and impact of preliminary indicators for each sustainable development domain in the framework

Based on overview of all the relevant aggregation methods in Section 2.3.4, it was decided that NCMC aggregation is the most appropriate method for the purposes of this project (refer to Section 3.3.6, below, for a discussion of the reasons for this choice of aggregation method). As explained in Section 2.3.2, an NCMC aggregation method does not require normalisation of data as it is not additive or multiplicative in nature. The data used in the present project is therefore not normalised.

3.3.5 Weighting

The six indicators reflecting the industry performance in each dimension of the triple bottom line are all equally weighted as these indicators are all assumed to be of equal importance. If equal weighting is deemed inappropriate, the statistical or participatory methods discussed in Section 2.3.3 can be used to allocate weight appropriately according to relevant expert knowledge, although no such effort was made in the present investigation. Equal weighting of all indicators, coupled with the symmetrical indicator structure (6 indicators measuring each dimension of the TBL), also implies that all dimensions of the TBL are assumed to be of equal importance. This is an important characteristic as no single dimension of sustainable development can be seen as more important than another (as correctly pointed out by, amongst others, Lozano (2008), Krajnc and Glavič (2005) and Brandi *et al.* (2014)). Sustainability depends on the the collective performance of the entire system, across all its dimensions.

Further, the sub-indicators for every indicator are equally weighted, but the weights of sub-indicators for different indicators do not necessarily have the same weight. As such, all indicators are of equal importance, but in the overall scheme all sub-indicators are not of equal importance. This is a result of the equal weighting of all the indicators – the relative weight of the sub-indicators depend on the number of sub-indicators of which an indicator is composed. For example, indicator Soci-4 (Human rights in the whole supply chain) is composed of 6 sub-indicators (therefore weighting $\frac{1}{6}$ each) while indicator Soci-5 (Negative impacts on local communities) is composed of only 3 sub-indicators (therefore weighting $\frac{1}{3}$ each). As all indicators are taken to be of equal importance, Soci-4 and Soci-5 both have a weight of $\frac{1}{6}$, but as a result each sub-indicator of Soci-4 has an implied overall weight of $\frac{1}{6} \times \frac{1}{6} = \frac{1}{36}$, while each sub-indicator for Soci-5 has an implied overall weight of $\frac{1}{6} \times \frac{1}{3} = \frac{1}{18}$.

Assigning equal weights to all indicators and not to all sub-indicators ensures that indicators composed from more sub-indicators are not implicitly more heavily weighted and therefore more important in the overall framework, as would be the case if all sub-indicators are equally weighted. This also ensures that all dimensions of sustainability are of equal importance, irrespective of the number of sub-indicators used to calculate the six indicators for each dimension.

If an indicator is deemed to be more important than another indicator within the same dimension its weight can be increased, as long as the weight of another indicator is decreased correspondingly. In other words, the relative importance of indicators within a dimension can be altered as deemed appropriate, but care must be taken to ensure the weights of all the dimensions remain equal. In contrast, the weights of sub-indicators can be adjusted as deemed appropriate without difficulty as the weights of the indicators are allocated independently from that of the sub-indicators from which they are composed. As such, altering sub-indicator weightings has no influence on the weight of the indicators themselves.

3.3.6 Aggregation

Many aggregation methods can be used to construct composite indices; each method having advantages and disadvantages to its use (as discussed in Section 2.3.4). Based on thorough consideration of these methods, a non-compensatory multi-criteria (NCMC) aggregation logic was deemed most appropriate for the present framework.

OECD and European Commission (2008) notes that multi-criteria problems, such as the comparison in the present framework, cannot be solved to find a single solution optimising all the criteria at the same time (the so-called 'utopia solution'). Instead an acceptable solution, allowing compromise, has to be found. However, compensability (note the difference between compromise and compensability) cannot be allowed in the aggregation process. If compensability is allowed, good performance in an aspect can offset poor performance in other aspects in the same dimension. When considering the social dimension, for example, compensability would allow employing a large number of employees to offset poor performance regarding health and safety or human rights in the supply chain or any of the other aspects measured. This is clearly not acceptable. Sustainable development, by definition, refers to the system as a whole and therefore performance in different aspects cannot be allowed to offset each other. By the same token, indicator weights have to be interpreted as importance coefficients and not as trade-off coefficients (as discussed in Section 2.3.4). As such, a non-compensatory logic, as employed by NCMC aggregation, was deemed to be a requirement.

Further, NCMC aggregation does not reward outliers as it only captures relative superiority or inferiority of industries with no regard to the extent of the advantage or disadvantage of an industry above another. This does, however, mean that without inspection of the value of individual underlying indicators, one cannot draw any conclusion as to the extent of superiority or inferiority of an industry compared to another. This also allows consistently good performance to potentially hide critically poor performance in a single or a few aspects. Additive- or multiplicative aggregation methods retains information regarding the magnitude of the advantage or disadvantage of an industry relative to another, however, these methods allow exceptionally good performance in a single aspect to compensate for consistently poor performance in other aspects. It can therefore be noted that when using NCMC aggregation, consistent performance is rewarded, while when using additive- or multiplicative aggregation methods, exceptional performance is rewarded. Based on the rejection of the plurality rule[1] as discussed in Section 2.3.4 and the above-mentioned importance of considering sustainable development as a system, NCMC aggregation, in which consistent performance is rewarded, is superior to the other methods.

Finally, NCMC aggregation does not require normalisation and therefore limits uncertainty introduced in the composite indicator (Munda and Nardo, 2009) and avoids the additional subjectivity that the choice of normalisation method brings in the construction of the composite indicator. The fact that information regarding the magnitude of indicator values is not captured in the aggregation process and no normalisation is required also allows the user to compare the composite indices for different dimensions. As only weights, that sum to a total of 1 for each dimension, are captured in the aggregation process, the performance of different dimensions can be compared directly. This is not the case when normalised indicator values are used, as these do not necessarily all sum to the same value for each dimension. The use of NCMC aggregation therefore allows and encourages sustainable development to be considered as an integrated system, instead of the traditional siloed consideration of the three dimensions of sustainable development. This addresses, at least partially, the concern that the framework encourages traditional siloed thinking regarding sustainability, uttered by one of the experts consulted in the validation process.

3.3.7 Framework validation

Validation of the framework by consulting relevant experts followed the step in which the aggregation method was decided. The aforementioned 32 preliminary indicators were used in this first iteration of the process in which the framework is first reviewed based on inputs from experts and then tested further by application of the framework, as illustrated in Figure 3.2. Only a single iteration of review and application of the framework was performed in this investigation. Relevant experts were identified by discussion with the project study leader and by recommendation from experts already contacted. Table 3.3 presents a summary of the four experts consulted in the validation process.

As indicated in Table 3.3, the experts consulted in the validation process represented several different perspectives, including sustainability research, the private sector involved in metal beneficiation, as well as research on the economic beneficiation of metals in South Africa. This variety of experts was

[1]Recall from Section 2.3.4, the plurality rule considers the industry that performs the best in most aspects to be superior, irrespective of the aspects in which it performs very badly.

Table 3.3: Experts consulted in the framework validation process

	Organisation	**Nature of work**	**Participation**
Expert 1	University of Stellenbosch	Sustainability research	Personal consultation, questionnaire
Expert 2	Council of Scientific and Industrial Research (CSIR)	Sustainability research	Questionnaire
Expert 3	Anglo American Platinum	PGM market development	Questionnaire
Expert 4	University of Cape Town	Beneficiation research	Questionnaire

chosen to ensure a balanced and comprehensive review of the contents of the framework and its possible utility.

A short questionnaire was used to capture the feedback from the experts in a formal and structured manner. Prior to completion of the questionnaire, each of the experts were introduced to the background, structure and objectives of the project by personal discussion or by discussion via telephone or Skype in order to ensure accurate feedback. This consultation process was approved by the Research Ethics Committee at Stellenbosch University and was completed in accordance with acceptable and applicable ethical guidelines and principles. A copy of the questionnaire as well as a copy of the written consent form (required to be completed by all respondents to accept the invitation to partake in the study) and the ethical clearance for the consultation process can be found in Appendix B.

The questionnaire presented a short introduction to the purpose of the preliminary framework as well as a brief description of the structure of the framework. These were followed by four questions to be answered by participants after studying the attached table presenting a list of the indicators included in the framework (including the aspect each indicator measures, an indication as to whether the indicator measures a positive- or negative impact and the units in which each indicator is measured). The four questions posed in the questionnaire were structured to provide guidance in the response of participants but remain considerably open-ended as to not restrict the response of participants and provoke an elaborate explanation of perceived shortcomings. The four questions were as follows:

1. Are the indicators considered in the framework comprehensive enough to ensure accurate comparison of development opportunities? If not, please

explain the shortcomings briefly.

2. Do you believe the framework has potential to be useful as a high level comparison tool for policymakers that need to decide which development opportunities should be prioritised? Please explain briefly.

3. Do you believe the use of publicly available sustainability information in the framework is an innovative way to make use of the growing amount of such sustainability information that is available in the public domain? Please explain briefly.

4. What are the shortcomings of the framework? Please explain briefly.

3.3.7.1 Responses to questionnaire

This section briefly discusses the responses of participants to the above-mentioned questions. Responses to questions 1 and 4 that motivated alterations to the framework are discussed in Section 3.3.7.2.

Apart from the insightful feedback on the indicators included in the framework discussed in Section 3.3.7.2, the first expert felt that the present framework has potential to be of use to inform decision-making. However, this expert did not feel that the framework could be viewed as innovative as many sustainability-based frameworks are already used for assessment and decision-support purposes. The novelty of this framework would therefore lie in its ease-of-use and the very rapid generation of results based on quantitative comparison.

The second expert also highlighted some possible improvements in terms of the included indicators, as discussed in Section 3.3.7.2. Further, this expert also expressed concern that the framework encourages siloed decision-making in which the three dimensions of the triple bottom line are considered separately and not in an integrated manner. The expert repeatedly emphasised the importance of integrated consideration of sustainability issues in which economic indicators are comparable with environmental and social indicators, thereby moving away from the traditional approach in which economic indicators were deemed most important, after which environmental and social aspects were considered. This very valid concern was at least partially addressed by making use of NCMC aggregation, in which indicators from different dimensions are comparable, as mentioned in Section 3.3.6 above. This facilitates more integrated consideration of the sustainability of industries, although aggregating the indices for the dimensions further into a single index that captures all three dimensions might aid the integrated consideration of aspects.

Responding to the question on the potential utility of the framework, the expert pointed out that the framework can be of use only if put into a specific context. Based on experience working as a decision-maker at the Department of Environmental Affairs in South Africa, the expert suggested that the framework might be useful in the 'development options' section of a scoping or environmental impact assessment (EIA) application, although it might only be a different way of doing what is already being done. Finally, answering the question on whether the framework is an innovative way of making use of publicly available sustainability information, the expert was of the opinion that the framework is not innovative in that sense and voiced concern that translating company-specific performance results to local or national targets may not be possible.

The third expert's response emphasised the lack of consideration of the current and future market for a specific industry and consideration of adjacent industries, as discussed in Section 3.3.7.2. Further, this expert was of the opinion that the high level view of the performance of industries, as provided by the framework, was a good start and that the framework has potential to be useful.

The fourth expert made remarks similar to those of the first expert regarding the indicators quantifying energy consumption and employment. Alterations were also made to indicator Econ-3 based on further comments by this expert, as discussed in Section 3.3.7.2. Further, the fourth expert was of the opinion that the framework has potential to be useful and noted that the "GRI is used as a basis for the establishment of industry practice standards by a number of organisations and governing bodies, and is thus a good starting point". In response to the question on whether the framework is an innovative way to make use of publicly available sustainability information, the expert felt it was indeed an innovative approach and noted that use of publicly available information is becoming increasingly popular. The expert did however warn that, as with any data, there are some reliability and consistency issues that are not yet well defined and that one should be well aware of this when using the present framework. Finally, the expert pointed out that it is important to contextualise what information the framework does and does not provide and what other tools or approaches can support or complement the framework.

3.3.7.2 Alterations following review process

This sub-section discusses the alterations made to the framework as a result of the responses of the experts consulted in the validation process.

The consultation process with experts produced several insights that were used to improve the indicators included in the framework. One of the experts pointed out that, based on personal experience, it is very hard to quantify the monetary value of indirect economic impacts even in a detailed investigation and therefore, considering the aim of the present framework to allow rapid comparison of opportunities, suggested that an impact score is used to quantify these impacts instead of a monetary value, as initially intended. As a result, indicator Econ-3 (Indirect economic impacts) was altered to be measured in terms of an impact score instead of a monetary value.

Further, this expert also pointed out that simply reporting the magnitude of material consumption, energy consumption, waste discharge and employment did not quantify these impacts sufficiently. The expert correctly pointed out that the life cycle impact of different materials differs and as such, an indicator quantifying the life cycle impact of the material consumption should be included to complement the indicator measuring the magnitude of material consumption. To illustrate the importance of considering the life cycle effects, consider platinum beneficiation by an industry producing catalytic converters and another producing platinum jewellery. Although both these products typically contain a similar small amount of platinum, the catalytic converter industry makes use of significant amounts of other materials (ceramic substrate, metal housing) apart from platinum, whereas the jewellery industry uses small amounts of other materials relative to platinum. Therefore, although the embedded life cycle impacts of the platinum will cancel out, the life cycle impacts of the other materials have to be considered explicitly. As a result, indicator Envi-1.3 (Life cycle impact of material consumption) was added to the framework.

Similarly, energy consumption from renewable sources is considered much more desirable than consumption of energy from non-renewable sources and this has to be taken into account in the framework. This was also mentioned by another expert, who considered it important to consider the source of energy along with the magnitude of consumption. As such, indicator Envi-2.2, which originally captured only scope 3 (upstream and downstream) energy consumption in terms of joules, was modified to also capture the life cycle impact of energy consumption. Envi-2.2 therefore now captures the magnitude of scope 3 consumption as well as the sources from which energy is attained in the form of an impact score. Capturing the magnitude of scope 3 energy consumption in terms of an impact score instead of joules of energy consumed was also deemed appropriate as, during application of the framework, it was found that organisations often fail to calculate and report scope 3 energy consumption, likely due to the complexity of the calculation. Approximation by impact score simplifies this problem considerably while still providing a reasonable indication of the likely impact, when given the due consideration.

Further, the expert suggested that the indicator measuring the amount of waste discharged should be complemented by another indicator accounting for the quality of the waste that is discharged. Discharging an amount of lightly contaminated process water, although undesirable, is obviously more desirable than discharging the same amount of highly contaminated water. As such, indicator Envi-4.3, capturing the overall quality of waste discharged by the industry, was added to the framework.

Finally, this expert and another pointed out that the indicator measuring the employment an industry is likely to create can be improved by also considering the level of the employment created. An industry requiring more skilled employees will have a larger positive socio-economic impact than an industry primarily requiring unskilled labour. This is especially applicable to developing countries (including South Africa) aiming to increase the average skill level of its workforce in order to address wider national socio-economic problems. These suggestions were incorporated into the framework by adding indicator Soci-1.2 (Impact of employment).

Linking closely to the comments on the level of employment, one of the experts also argued that enhancement of national skills and investment in research and development (R&D) are often of more significance in the area of downstream beneficiation than direct employment. This argument was motivated by the expert's increasing conviction that simply developing downstream beneficiation industries is less effective than focusing on enhancing national skills and innovation which, if managed properly, results in development of downstream as well as so-called sidestream industries. The potential of an industry to facilitate the development of upstream, downstream and sidestream industries was only partly considered in the framework as part of indicator Econ-3 which measures indirect economic impacts. The scope of indicator Econ-3 was subsequently expanded to include explicit consideration of these facilitating effects. The level of technology used by an industry, the level of innovation and level of investment in research and development were identified as factors likely indicative of the significance of these effects.

Another expert pointed out that the environmental indicators initially included in the framework did not quantify the loss of resources from the natural environment, for example loss of biodiversity, sufficiently. The scope of the indicator Envi-6, quantifying the environmental impacts of the supply chain and customers of the industry, was therefore adjusted to incorporate these impacts for the industry itself, as well as for the industries upstream and downstream.

Further, another expert pointed out that the economic indicators initially included in the framework did not sufficiently consider factors regarding the saturation of the market and the impact of adjacent or supporting industries. Adjacent and supporting industries can provide knowledge and facilities that can be leveraged and therefore improve the overall feasibility of the new industry. Likewise, market saturation can have a significant impact on the feasibility of an industry. As such, it was decided that an indicator (Econ-5) that captures the overall competitiveness of an industry had to be included and thereby address the aforementioned shortcomings. Of course, the quantification of industry competitiveness has been subject to much debate and it is therefore not a trivial process to find or develop an indicator to quantify it. For the present work, Michael Porter's revolutionary Five Forces model (Porter, 1980) and his subsequent Diamond of National Advantage (Porter, 1990) were used to develop an indicator to quantify competitiveness in the form of an impact score. The indicator quantifies competitiveness in terms of four factors, namely:

- Factor conditions, which include basic- and specialized factors, referring to factors such as the availability of a suitable workforce or the availability of specialized knowledge, that ultimately improves the international competitiveness of an industry;
- Demand conditions, which considers the impact of both the character and size of local demand for the products produced by the industry on its international competitiveness;
- Related and supporting industries, with which knowledge and other resources can be leveraged;
- Rivalry, considering that tough competition can discourage the establishment of a new industry but can improve the international competitiveness of an industry once established.

More detail regarding this indicator is provided in its scope statement presented in Appendix A (kindly refer to Section A.2).

Further, in the process of reviewing literature to inform the development of the indicator quantifying industry competitiveness, PESTLE analysis was also considered. PESTLE, a mnemonic which when expanded denotes **P**olitical, **E**conomic, **S**ocial, **T**echnological, **L**egal and **E**nvironmental, outlines factors to consider regarding a market that an organisation is operating in, or attempting to enter (PESTLE Analysis, 2016). It was noted that the framework, up to that point, did not consider the economic impacts of political and legal factors as suggested in PESTLE analysis. It was also noted that the economic impacts of cultural and demographic factors, which are considered as part of the social factors in PESTLE analysis, were not considered in the framework. Although technological factors are not explicitly considered, such factors are implicitly considered as part of the factor conditions (Econ-5.1) that form part of the aforementioned indicator quantifying competitiveness, as well as part of indicator Econ-3 capturing indirect economic impacts. It was therefore deemed necessary to include political, legal factors and cultural factors as part of the economic dimension of the framework and as such, a new indicator (Econ-6) was developed. This indicator therefore considers three aspects, namely:

- Political factors, considering the level of government influence in the economy and the policies of the government (in terms of incentive schemes for particular industries, for example);
- Regulatory factors, considering regulatory policy in terms of consumer, safety and labour laws and their enforcement, as well as applicable trade regulations and penalties;
- Cultural and demographic factors, considering the impact of the cultural diversity and demography in a country, as well as the prevalent cultural convictions and stigmas relating to some industries.

More detail regarding this indicator is provided in its scope statement presented in Appendix A (kindly refer to Section A.2).

The development and inclusion of these two indicators also served to replace two indicators that were found to be problematic during the initial data collection phase. It was found that calculating the value of indicator G4-EC4, quantifying financial assistance expected to be received from government, was troublesome in that such assistance schemes are generally very complex, interwoven and not necessarily similar throughout an entire industry or constant over an extended period of time (as would be required if comparison of opportunities are to be done at expected future conditions). Similarly, indicator G4-EC7, measuring expected infrastructure investments by the industry, was difficult to calculate in monetary terms as such investments may be generalisable for an industry to some extent (when considering investments crucial for the operation of the industry, for example), but are very often influenced by the performance of organisations in the industry and governmental assistance programmes, which again are not generally constant over extended periods of time. The scope of indicator Econ-3, measuring indirect economic impacts, was therefore modified to include expected infrastructure investments in its consideration of potential impact. Indicators G4-EC4 and G4-EC7 were removed from the framework and considered to be adequately quantified by the two new indicators and the existing ones.

Table 3.4, below, presents the final indicators included in the framework after making the alterations and additions based on the review process. This table also reflects the final grouping, impact and weighting of each indicator.

3.4 Chapter 3: Conclusion

This chapter presented the process followed to develop the framework that was the primary objective of this project. The purpose of the framework (to facilitate the high level, typically scoping phase comparison of different metal beneficiation industries) and the symmetrical indicator structure it makes use of, was discussed. The process of developing the framework was then discussed. The decision to use the GRI G4 Sustainability Reporting Guidelines as the basis for the framework, the selection of indicators used in the framework, as well as the decisions to use equal weighting and NCMC aggregation of indicators, were discussed. The validation of the framework content by consulting relevant experts and the subsequent alterations were discussed. The next step in the framework development methodology was the application of the framework to case study industries and the industries used for this purpose are therefore introduced in the next chapter.

Table 3.4: The final indicators included in the framework, along with the grouping, impact and weighting of each

Aspect	ID	Indicator	Impact	Weight
Economic Indicators				
Economic performance	**Econ-1**	**Economic value**	+	**1/6**
	Econ-2	**Climate change risks**	+	**1/6**
Indirect economic impacts	**Econ-3**	**Indirect economic impacts**	+	**1/6**
Procurement practices	**Econ-4**	**Local suppliers**	+	**1/6**
Strategic considerations	**Econ-5**	**Competitiveness**		**1/6**
	Econ-5.1	Factor conditions	+	1/4
	Econ-5.2	Demand conditions	+	1/4
	Econ-5.3	Related & supporting industries	+	1/4
	Econ-5.4	Rivalry	+	1/4
	Econ-6	**Socio-economic factors**		**1/6**
	Econ-6.1	Political factors	+	1/3
	Econ-6.2	Regulatory factors	+	1/3
	Econ-5.4	Cultural & demographic factors	+	1/3
Environmental Indicators				
Material consumption	**Envi-1**	**Material consumption**		**1/6**
	Envi-1.1	Materials by weight	–	1/3
	Envi-1.2	Water withdrawal	–	1/3
	Envi-1.3	Life cycle impact of material consumption	–	1/3
Energy	**Envi-2**	**Total energy consumption**		**1/6**
	Envi-2.1	Energy consumption (Scope 1 & 2)	–	1/2
	Envi-2.2	Life cycle impact of energy consumption	–	1/2
Emissions	**Envi-3**	**Total gaseous emissions**		**1/6**
	Envi-3.1	Greenhouse gas emissions (Scope 1 & 2)	–	1/4
	Envi-3.2	Greenhouse gas emissions (Scope 3)	–	1/4
	Envi-3.3	Ozone-depleting substances (ODS) emissions	–	1/4
	Envi-3.4	NOx, SOx and other emissions	–	1/4
Effluents & waste	**Envi-4**	**Total waste discharge**		**1/6**
	Envi-4.1	Water discharge	–	1/3
	Envi-4.2	Waste discharge	–	1/3
	Envi-4.3	Overall quality of waste	+	1/3
Products & services	**Envi-5**	**Products & packaging materials reclaimed**		**1/6**
Supplier environmental	**Envi-6**	**Supply chain environmental impacts**		**1/6**

Table 3.4: The final indicators included in the framework, along with the grouping, impact and weighting of each (continued)

Aspect	ID	Indicator	Impact	Weight
Social Indicators				
Sub-category: Labour practices & decent work				
Employment	**Soci-1**	**Total employment**		**1/6**
	Soci-1.1	Number of new employee hires	+	1/2
	Soci-1.2	Impact of employment	+	1/2
Occupational health & safety	**Soci-2**	**Health & safety risk**	–	**1/6**
Training & education	**Soci-3**	**Average hours of training for employees**	+	**1/6**
Sub-category: Human rights				
Human rights assessments	**Soci-4**	**Human rights in whole supply chain**		**1/6**
Supplier assessment for labour practices	Soci-4.1	Negative impacts for labour practices in the supply chain	–	1/6
Non-discrimination	Soci-4.2	Incidents of discrimination	–	1/6
Freedom of association	Soci-4.3	Significant risk of freedom of association in operations and suppliers	–	1/6
Child labour	Soci-4.4	Significant risk of child labour in operations and suppliers	–	1/6
Forced or compulsory labour	Soci-4.5	Significant risk of forced or compulsory labour in operations and suppliers	–	1/6
Supplier human rights assessments	Soci-4.6	Human rights impacts in the supply chain	–	1/6
Sub-category: Society				
Local communities	**Soci-5**	**Negative impacts on local communities**		**1/6**
Local communities	Soci-5.1	Negative impacts on local communities	–	1/3
Anti-corruption	Soci-5.2	Risks related to corruption	–	1/3
Supplier assessments for impacts on society	Soci-5.3	Negative impacts on society in the supply chain	–	1/3
Sub-category: Product Responsibility				
Customer health & safety	**Soci-6**	**Health and safety impacts of products and services**		**1/6**
Customer health & safety	Soci-6.1	Health and safety impacts of products and services	–	1/2
Marketing & communications	Soci-6.2	Sale of banned or disputed products	–	1/2

Chapter 4

Case study: Background

Applying the developed framework to case study industries forms the third phase of the methodology used in this project (as illustrated in Figure 3.2 in Chapter 3) and serves to test the utility of the framework and identify the shortcomings of its use. This phase therefore forms an important part of the process of validating the framework and the results it generates. Platinum beneficiation was chosen as case study and this chapter therefore presents the reasoning to this choice (Section 4.1), as well as some background of the global platinum value chain (Section 4.2). Sub-section 4.2.1 presents a brief overview of the major platinum producers globally and the processes typically used to produce pure platinum metal. Sub-section 4.2.2 then presents an overview of the major uses of platinum and the corresponding geographical spread of global platinum demand. Finally, based on the background given in earlier sections, Section 4.3 discusses the specific platinum beneficiation industries which were used to test the utility of the framework, as described in the next chapter.

4.1 Choice of a suitable case study

As previously noted, the present framework was developed to be used for comparison of potential metal beneficiation industries. Many industries fall within this realm and can be used to illustrate and test the utility and shortcomings of the framework. However, it is important to use industries for which the relevant information, of sufficient quality, is readily available (generally implying that well established industries are favourable). It is further of value if the case study industries are chosen not only to be relevant in terms of validation of the framework, but also in terms of actual development in a country, preferably South Africa, such that the results generated by application of the framework are of use wider than simply validating the framework.

Potential industries that can be developed in South Africa to which the framework can be applied are bountiful as a result of South Africa's huge mineral wealth. South Africa is especially well endowed in terms of platinum group metals (PGMs, including platinum, palladium, rhodium, ruthenium, iridium and osmium), with the Bushveld Complex in the North-West, Limpopo and Mpumalanga provinces being the largest primary deposit of PGMs in the world. As a result, at least 70 per cent of world's platinum reserves (Mudd, 2012) can to be found in South Africa (some sources report in excess of 80 per cent (Cawthorn, 2010; South African Chamber of Mines, 2015)). The South African Reserve Bank (2014) reported that in 2013, platinum exports accounted for 9.5 per cent of total South African merchandise exports and 2.4 per cent of gross domestic product (GDP).

However, minor beneficiation of these resources takes place in South Africa, with the manufacture of catalytic converters being the only notable platinum beneficiation industry in South Africa (producing 13 per cent of the world's platinum catalytic converters in 2013) (Baxter, 2014). Given the enormous size of South Africa's platinum reserves and the extent to which the Bushveld complex is mined, the contribution of the platinum industry to the South African economy could be far greater than it has traditionally been (Stilwell, 2004). This is due to the fact that South Africa exports the vast majority of its platinum production without any economic beneficiation beyond production of the pure metal. The South African Chamber of Mines (2015) reported that in the 2013 calendar year, South Africa exported 89.5 per cent of its total platinum group metal production, meaning only 10.5 per cent was sold locally to be beneficiated in South Africa. However, as mentioned before, the South African government has recognised the comparative advantage that South Africa has with its vast natural resource endowment and has made it a strategic objective to translate this comparative advantage to a "national competitive advantage" (South African Department of Mineral Resources, 2011). The Department of Mineral Resources' Beneficiation Strategy for the Minerals Industry in South Africa, published in June 2011, aims to provide a framework to facilitate this translation (South African Department of Mineral Resources, 2011).

It is therefore clear that ever-increasing emphasis is required and is indeed being placed on enhancing local beneficiation of South Africa's natural resources – prominently platinum. Platinum is also used in a wide range of well established industries globally, with accurate information generally easily attainable for many of these industries. As such, the beneficiation of platinum in South Africa is an ideal and relevant case on which to test the utility of the framework developed in this study.

4.2 Global platinum value chain

This section now presents an overview of the global platinum value chain to serve as a foundation for the final section of this chapter which discusses the choice of specific platinum beneficiation industries used to test the framework, as described in the next chapter.

4.2.1 Production of platinum

Global platinum production is limited to a few deposits where the grades are high enough to make extraction of the PGMs economically viable. The Merensky, Platreef and Upper Group 2 (UG2) reefs of the Bushveld Complex in South Africa, the Great Dyke reefs in Zimbabwe and the JM reef of the Stillwater Complex in Montana, United States of America, are the only major primary PGM deposits in the world. Major secondary deposits include the Sudbury Irruptive Complex in Ontario, Canada, and deposits in the Noril'sk-Talnakh District, the Urals and at Kondyor in Russia. The fairly small Jinchuan deposit in China is another example of a secondary deposit (Mudd, 2012).

Several authors have recently reported global platinum reserve and resource figures (Cawthorn, 2010; Mudd, 2012; United States Geological Survey, 2014). The United States Geological Survey (2014) compared several estimates and concluded that the Bushveld Complex contained platinum resources[1] amounting to 37 000 tonnes (along with 25 000 tonnes of palladium and 4 800 tonnes of rhodium, therefore 67 000 tonnes of PGMs in total). The United States Geological Survey (2014) further also reported an estimate of 40 000 tonnes of undiscovered[2] platinum resources in the Bushveld Complex. The resource estimate by the United States Geological Survey (2014) corresponds fairly well to the 64 000 tonnes of PGM resources reported by Mudd (2012). Based on that figure, Mudd (2012) reported that South Africa has 70.9 per cent of global PGM resources. However, it is important to note that the mineral resources of the Bushveld Complex are generally reported up to a depth of 2 kilometres (traditionally seen as the maximum economically exploitable depth). Improving mining technology might, in the near future, make deeper mining profitable and thereby increase the PGM resource estimates of the Bushveld Complex dramatically (Cawthorn, 2010).

[1]Resource includes measured, indicated and inferred resource size based on geological information (kindly refer to United States Geological Survey (2014)).

[2]Undiscovered resource refers to resources based on geological information that is insufficient to meet the requirements for defining inferred mineral resources.

4.2.1.1 Major producers of platinum

As a result of its extensive platinum resources, South Africa continues to dominate global production of platinum despite continuing labour unrest and increasing production cost. The burden of the labour issues and high production cost is reflected in the decreasing South African production footprint, as illustrated in Figure 4.1, below. South Africa, however, still produced in excess of 70 per cent of global platinum in 2013, followed by Russia (13.6 per cent in 2013), Zimbabwe (7 per cent in 2013) and North America (5.5 per cent in 2013).

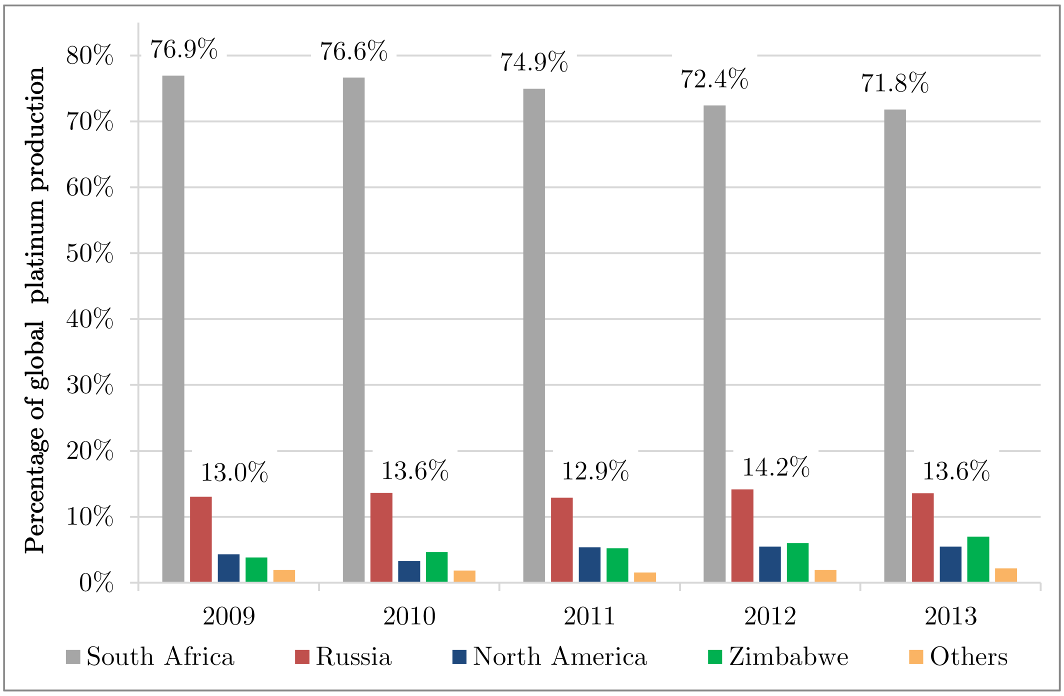


Figure 4.1: Percentage of global platinum production by major PGM producing area from 2009 to 2013 (Johnson Matthey, 2014)

It it worth noting that platinum production from the Great Dyke in Zimbabwe has increased steadily from zero production in 2004 to 400 000 oz (11.34 tonnes) in 2013. Mudd (2012) reported that the Great Dyke of Zimbabwe contained 8 600 tonnes of PGM resources (comparing well to the 8 700 tonnes reported by United States Geological Survey (2014)) and based on these estimates the Great Dyke contains about 9.5 per cent of global PGM resources. Further, exploitation of these resources has only recently started and the PGM industry in Zimbabwe therefore has considerable growth potential. Increasing PGM production in Zimbabwe, coupled with neighbouring South Africa's already dominant position in global platinum production, presents strong support for the development of local beneficiation industries in southern Africa.

Global platinum production is limited to a fairly small number of producers as a direct effect of the limited number of PGM deposits globally. Figure 4.2, below, presents the annual platinum production or sales of some of the major global platinum producers (collected from their respective annual reports).

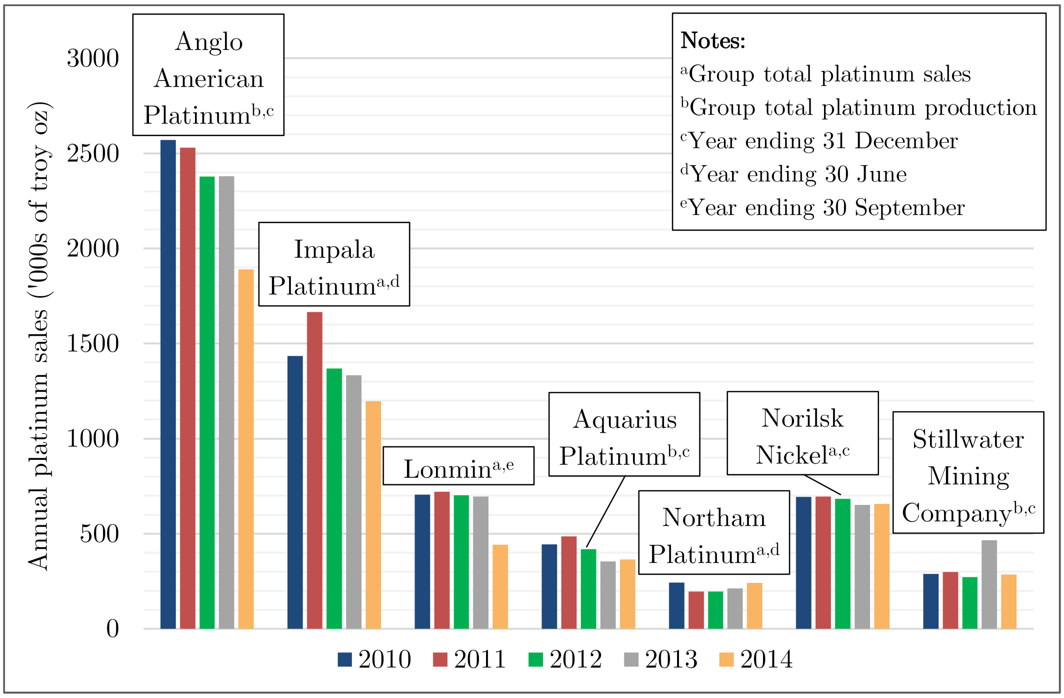


Figure 4.2: Annual platinum sales by major platinum producers

4.2.1.2 Typical platinum production processes

This section presents a brief overview of the most prominent processes used to produce platinum (and the other PGMs) in pure metal form and where these processes are generally performed geographically.

Few well established processing routes, or variations thereof, are generally used throughout the industry. The following steps are generally followed in the extraction of platinum group metals (Crundwell *et al.*, 2011):

1. **Mining and comminution**
   Mining and crushing and/or milling the ore to the desired size distribution, thereby liberating the PGM containing grains in the host rock.

2. **Physical concentration**
   The first concentration step, often involving gravity concentration and/or

flotation that produces a flotation concentrate rich in base metal sulphides and PGMs.

3. **Pyrometallurgical concentration**
   Smelting and converting of the flotation concentrate to a nickel-copper sulphide matte containing a higher concentration of PGMs.

4. **Base metal refining**
   Separating the PGMs from the base metals by leaching of the base metals, producing a PGM-rich concentrate of 50 to 70 per cent PGMs.

5. **Precious metal refining**
   Production of high purity individual PGMs by first separating the metals, followed by purification and reduction to metal.

Figure 4.3 illustrates the locations of some prominent processing facilities worldwide (kindly refer to Crundwell *et al.* (2011) for further detail on global processing facilities and Johnson Matthey (2012) for detail on platinum production in the Russian Federation). In Figure 4.3 every balloon does not necessarily refer to a single operation (several mines usually feed a processing facility, with more than one concentrating operation sometimes feeding a base metal refinery).

Steps 1 to 4, as listed above, almost always takes place close to the location where the ore is mined (likely due to the low value and high volume of the metal in these stages), with step 5 also sometimes completed at the same location. In South Africa, Anglo American Platinum (Amplats), Impala Platinum (Implats) and Lonmin all have the complete processing chain (steps 1 through 5) close to their mines. Northam Platinum in South Africa, Stillwater Mining Company in the U.S.A. and Norilsk Nickel in Russia all have processing plants for processing up to base metal refining (steps 1 through 4), selling the concentrate from their base metal refineries or having it toll-refined by a third party.

The PGM concentrate from Northam's base metal refinery is refined by Heraeus (Jones, 2005). The refining by Heraeus originally took place at its facilities in Hanau, Germany, but now takes place at its refinery in Port Elizabeth. Heraeus is a global leader in precious metal processing with more than 100 subsidiaries in 38 countries, producing products for, amongst others, the electronics, automotive, medical, chemical and pharmaceutical, and glass industries (Heraeus Group, 2016).

Jones (2005) reports that 5 companies operate smelting facilities in southern Africa, namely: Anglo American Platinum, Impala Platinum, Lonmin Platinum, Northam Platinum and Makwiro Platinum in Zimbabwe. Makwiro

Platinum (Zimplats) forms part of the Impala Platinum Group (55% owned by Impala) and is therefore indicated as part of Implats' operations in Figure 4.3. Zimplats has a concentrate offtake agreement to refine its production at Implats' refinery (Impala Refining Services, IRS) in South Africa.

According to Jones (2005), Stillwater Mining Company operates the only primary smelter of PGMs other than the smelting facilities operated by 5 companies in southern Africa. All PGM production from Stillwater Mining Company's base metal refinery is toll-refined by Johnson Matthey (Stillwater Mining Company, 2014). Johnson Matthey offers worldwide precious metal trading services, produces PGM products for several industries (several metallic products, catalyst and chemical products, medical and pharmaceutical products and advanced glass technologies) and also offers precious metal refining services (Johnson Matthey, 2016). Johnson Matthey has two precious metal refining plants, one in West Deptford near Philadelphia in the U.S.A. and another in Royston in the U.K. Johnson Matthey also operates an evaluation and smelting facility in Brimsdown, U.K.

Vale operates the Vale Acton Refinery in Acton, U.K., while Umicore operates one of the world's leading facilities that processes complex waste streams to recycle the precious metals and other non-ferrous metals it contains in Hoboken, Belgium (Umicore, 2016).

Norilsk Nickel operates several facilities that produce significant amounts of PGMs as co-products from its nickel producing operations. The majority of its PGM production is refined at the Krastsvetmet refinery in Krasnoyarsk, Russia, although several other state-owned refineries also produce PGMs.

Figure 4.3 clearly shows that mining companies generally do processing steps up to base metal refining (producing a PGM concentrate of 50 to 70 per cent PGMs, containing about 25 per cent platinum). The low mass and high value of PGM concentrate allows precious metal refineries to be located elsewhere, as the large number of precious metal refineries in Europe illustrates. Many of these refineries do not only refine concentrate from primary producers, but also process secondary sources of precious metals such as scrapped jewellery and end-of-use catalysts to recycle the precious metals. The high value of PGMs results in a strong drive to recycle as much of these metals as possible with about 25% of global platinum demand supplied by recycling in 2013 (Johnson Matthey, 2014). Nassar (2015) reports that PGM substitution potential for current high-volume applications is limited by a multitude of factors, one of which is the high efficiency with which PGMs can be (and are) recovered and recycled. The location of refineries therefore seems to be influenced not only by the location of primary sources of PGMs, but also by the location of industries with high PGM consumption, serving as both consumers

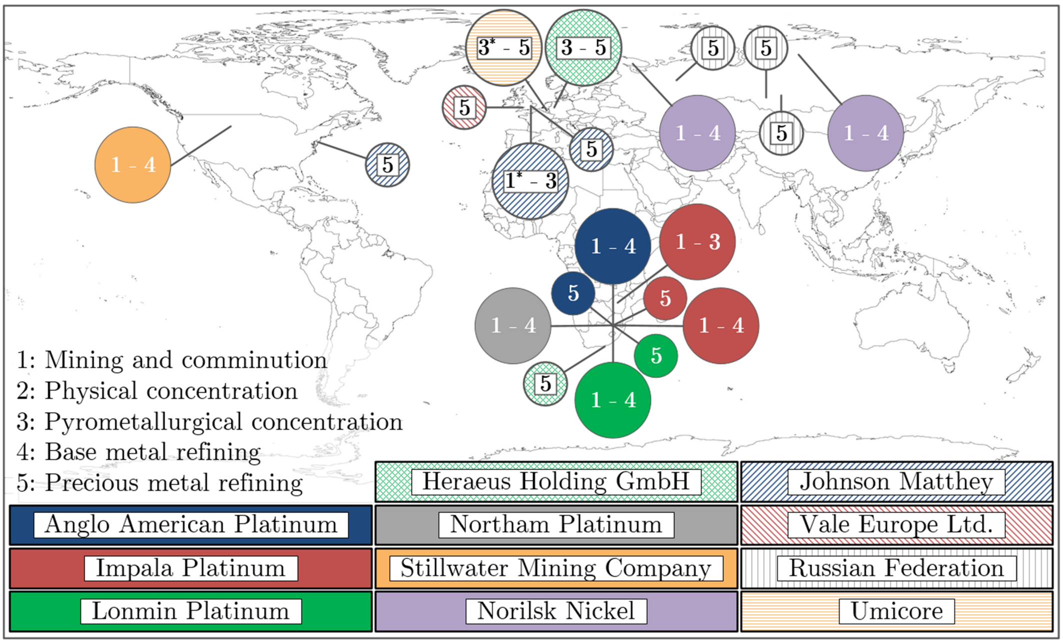


Figure 4.3: The location of some prominent global processing facilities (*uses recyclable PGM rich material, such as spent process catalysts and catalytic converters, as feedstock instead of mined ore)

for the pure precious metals the refinery produces and as sources of recyclable PGM-containing input material. Further, Figure 4.3 does not show several refineries that are primarily aimed at base metal production (mostly nickel) but also produces a small amount of PGMs that forms part of the feed ore (for example Glencore's Nikkelverk refinery in Kristiansand, Norway, and Sumitomo Mining Company's Niihama Nickel refinery in Niihama, Japan). The location of base metal deposits and production facilities therefore also influences the location of precious metal refineries.

4.2.2 Consumption of platinum

This section aims to present a brief overview of the use of platinum globally. The different applications in which platinum is used, as well as the geographical spread of each use, will be discussed shortly.

Platinum is used in a variety of applications, including as catalytic component in automotive catalytic converters and industrial catalysts, and as construction material for equipment used in the glass industry. Platinum is also used in some medical and biomedical components, electronic and electrical components, jewellery and for investment purposes. Figure 4.4, below, illustrates various breakdowns of global platinum use in 2013, based on data published by Johnson Matthey. In Figure 4.4, it can be noted that catalytic converters, used to decrease automotive exhaust emissions, remained the biggest consumer of platinum globally (37%). Jewellery was the second largest consumer (33%), followed by platinum use for investment purposes (9%).

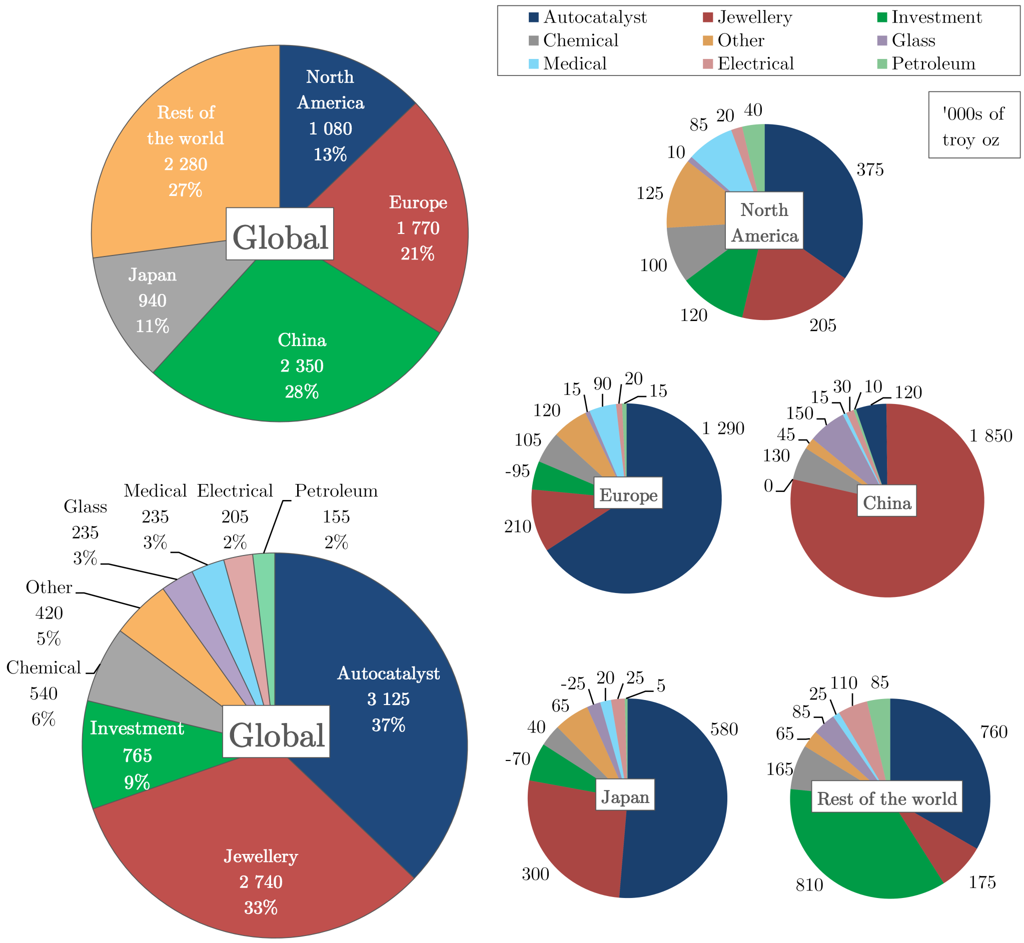


Figure 4.4: Breakdown of global platinum demand in 2013 (negative values indicate more platinum was produced by recycling from a sector than was consumed by the sector. Values in thousands of troy ounces) (Johnson Matthey, 2014)

Further, it can be noted that China was the largest consumer of platinum in 2013 (28%), followed by Europe (21%), North America (13%) and Japan (11%). The remaining 27 per cent was consumed by the rest of the world. China is, by a significant margin, the largest consumer of platinum for jewellery purposes globally and platinum demand in China was dominated by the jewellery sector, accounting for 74 per cent of platinum demand in China, in 2013. Platinum use in Europe, North America and Japan was dominated by use in catalytic converters, followed by use in jewellery. The significance of the automobile industries in Europe and Japan is apparent when it is noted that the manufacture of catalytic converters accounted for 72- and 62 per cent of platinum demand in 2013, in these areas, respectively.

Figure 4.5, below, illustrates the historical global gross platinum demand and recycling for 2004 through 2013 (note that Medical and Biomedical demand was included in Other before 2005). From Figure 4.5 it can be noted that global platinum demand has grown slightly over the decade shown, even though demand decreased significantly from 2007 to 2009 as a result of the global financial crisis (Mudd, 2012). Further, the importance of the global autocatalyst industry as consumer of platinum has decreased, despite increased demand for motor vehicles, although this sector still accounted for the largest part of global platinum demand. This decrease is as a result of the increased substitution of platinum in autocatalysts as well as continued efforts to decrease the platinum loadings required (South African Chamber of Mines, 2015).

Platinum demand by the jewellery sector remained fairly consistent, however, the influence of the platinum price on jewellery demand is apparent. The combined peak in platinum demand and high average annual platinum prices in 2007 and 2008 contributed to decreased platinum demand by the jewellery

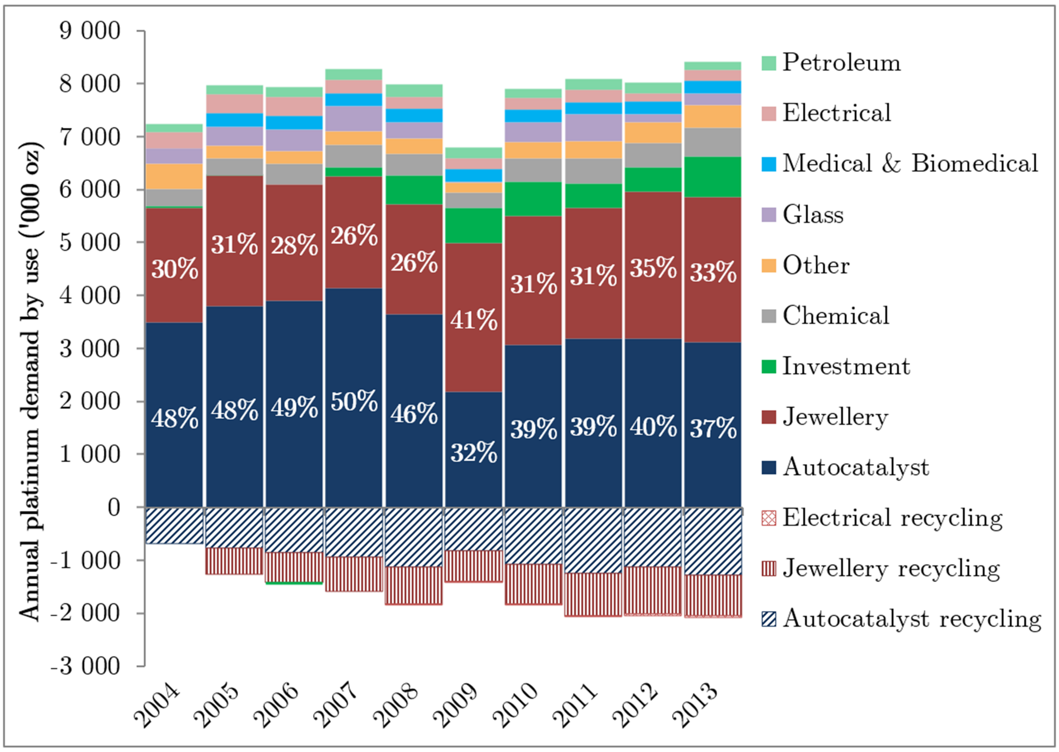


Figure 4.5: Annual gross platinum demand and recycling, by use (values given in thousands of troy ounces) (Johnson Matthey, 2014)

industry, followed by a spike in platinum demand for jewellery in 2009 when the platinum price was the lowest in 3 years, as global platinum demand by the automotive sector receded (Watts *et al.*, 2010). Slightly lower platinum prices, along with increased demand for platinum jewellery in China and India, once again contributed to increased demand by the jewellery industry in 2012 and 2013 (South African Chamber of Mines, 2015).

Further, platinum demand for investment purposes increased substantially over the decade under consideration. The launch of the Platinum Exchange Traded Fund (ETF) by Absa in South Africa contributed to a 68 per cent increase in platinum demand for investment from 2012 to 2013. Finally, platinum recycling also increased steadily from 2004 to 2013. Secondary production of platinum by recycling was promoted by the damage to South Africa's reputation as a reliable supplier of platinum as a result of the continuing labour unrest (South African Chamber of Mines, 2015).

4.2.2.1 Catalytic converters

Catalytic converters in automotive exhaust systems convert unreacted hydrocarbons, carbon monoxide (CO) and nitrogen oxides (NOx) produced during incomplete combustion to less harmful chemical compounds. In most countries regulatory acts enforce the use of catalytic converters to limit air pollution, and thus the environmental impact of these harmful compounds, and the global catalytic converter industry therefore accounted for the majority of the global PGM demand since the 1980s.

Platinum, palladium and rhodium are used in catalytic converters, with two-way catalytic converters for diesel engines requiring higher platinum loadings than catalytic converters for petrol engines. The platinum loading of a converter typically ranges between 1 and 15 grams, depending on the size and engine type of the vehicle (Yang, 2009).

Globally, regulations regarding emissions from automobiles are becoming increasingly stringent and the global drive for increased automobile efficiency results in increased use of diesel engines, both of which results in increased use of platinum in the catalytic converter industry. Further, historical trends indicate that worldwide use of automobiles will continue to increase, especially as developing economies (notably the BRICS countries: Brazil, Russia, India, China and South Africa) grow their economies and automotive industries. It is therefore expected that the catalytic converter industry will remain significant with regard to the use of PGMs (Dewar, 2012; Wilburn and Bleiwas, 2004).

Figure 4.6 shows the distribution of global platinum demand by the catalytic converter industry. Europe and Japan, combined, was responsible for 60 per cent of gross demand in 2013, accounting for 41 per cent and 19 per cent, respectively. North America and China was responsible for 12 per cent and 4 per cent of demand, respectively, with the rest of the world accounting for the remaining 24 per cent. The South African Chamber of Mines (2015) reported that South Africa produced 13 per cent of the catalytic converters produced globally in 2013 and this 13 per cent therefore forms part of the 24 per cent reported for the rest of the world in Figure 4.6.

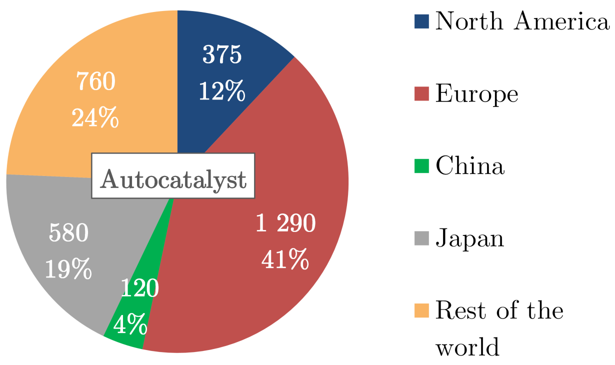


Figure 4.6: Platinum demand for use in autocatalysts in 2013 (values given in thousands of troy ounces) (Johnson Matthey, 2014)

The South African catalytic converter industry is fairly well developed and Dewar (2012) reported that in 2011 about 15 per cent of locally mined PGMs were beneficiated in the production of catalytic converters. At a global market share of 15 per cent in 2011, the catalytic converter industry is one of the very few manufacturing industries where South African production is significant globally. However, projections indicate that local PGM beneficiation by the catalytic converter industry is decreasing as production is moved to other global locations, mainly due to uncertainty around changes to government incentive programmes in South Africa (Dewar, 2012). This is substantiated by the fact that the South African Chamber of Mines (2015) reported a market share of 13 per cent for 2013, indicating a 2 per cent market share loss in 2 years. Furthermore, the high cost of PGMs is driving interest in development of alternative technologies that would reduce or eliminate the need for PGMs in catalytic converters. Work done by General Motors Corporation and Honda Motor Company Limited on such alternatives has shown some promise, but it remains to be seen if large scale development and implementation will follow (Wilburn and Bleiwas, 2004).

The catalytic converter industry in South Africa holds great potential for further development, given suitable support from the PGM producers (mines) and the South African government (Dewar, 2012). However, even though the demand for catalytic converters will likely continue to grow for at least the next two decades, catalytic converters may be seen as an interim technology – a temporary solution to the emission problem until a better technology comes along (Wilburn and Bleiwas, 2004). Fuel cell technology for automotive propulsion and electric propulsion technology is maturing rapidly and endangers the long term sustainability of the catalytic converter industry.

4.2.2.2 Jewellery

Platinum is widely used in the jewellery industry as its white colour tends to increase the sparkle and appeal of gemstones, and the smooth lines of platinum jewellery are found aesthetically pleasing by many. Platinum is very soft and is therefore often alloyed with palladium (typically 10% palladium) to improve hardness and strength. The resulting strength of the alloy allows smaller and thinner stone settings, and therefore allows more light to refract off the gemstone (United States Geological Survey, 2004).

The jewellery industry remains the second largest user of platinum globally since demand by the catalytic converter industry passed demand by the jewellery industry in the 1980s (refer to Figure 4.5, above, and Mudd (2012)). Figure 4.7, below, shows the global platinum demand by the jewellery industry in 2013. Platinum jewellery is most popular in Asia (accounting for at least 79% of demand in 2013), especially China (68% of demand in 2013), where platinum jewellery purchases increased five-fold between 1997 and 2002 (Wilburn and Bleiwas, 2004). Japan accounted for 11 per cent of demand by the jewellery industry in 2013, followed by Europe and North America, accounting for 8 and 7 per cent, respectively. Demand by China and Japan accounted for 47 per cent and 26 per cent, respectively, in 2004. Platinum demand by the Chinese jewellery industry therefore increased by 21 per cent from 2004 to 2013, compared to a decrease of 15 per cent for Japanese demand over the same period. The growth in Chinese platinum jewellery sales reflects the increasing prosperity of the nation and emphasises its increasing importance in the platinum jewellery market. India has historically been the largest market for gold jewellery globally and the platinum jewellery market in India is growing. However, demand for platinum jewellery in India is sensitive to the platinum:gold relative price, but the Indian market can nonetheless become important in the near future, due to the size of the market (Watts *et al.*, 2010).

The nature of the jewellery market means cultural trends and societal preferences play an important role in the demand. However, based on the rarity of platinum, its useful properties and its appearance, it is unlikely that platinum

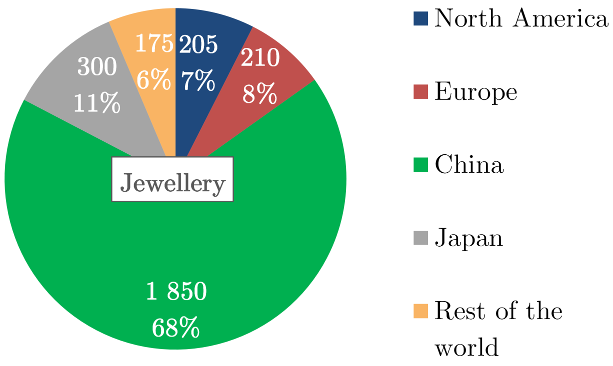


Figure 4.7: Platinum demand for use in jewellery in 2013 (values given in thousands of troy ounces) (Johnson Matthey, 2014)

jewellery will become less desirable (United States Geological Survey, 2004). It has traditionally been noted that in periods of poor industrial platinum demand, platinum jewellery demand increased and served as a vital cushion to falling prices (Watts et al., 2010). Jewellery is therefore expected to remain an important part of the global platinum value chain for the foreseeable future.

4.2.2.3 Investment

Precious metals have long been used for investment purposes – investment in gold began as long as 2500 years ago. Precious metals are often regarded as safe havens that offer investors protection against inflation and/or geopolitical risk, along with a significant diversification effect for investment portfolios (Fassas, 2012). Platinum coins and bars are, or have been, produced for investment purposes in various countries, including the United States of America, Canada, Australia and Japan (Johnson Matthey, 2013).

With the launch of commodity exchange-traded products (ETPs)[3] in 2003, investors could, for the first time, easily and cost-effectively access commodities. Commodity ETPs grew rapidly, such that close to 700 commodity ETPs were available globally in 2011 (Fassas, 2012). It is therefore no surprise that investment in platinum grew strongly, increasing from about 1 per cent of global platinum demand in 2004 to 9 per cent of demand in 2013 (refer to Figure 4.5, above).

[3]Exchange-traded products (ETPs) are stock exchange securities that continuously track the performance of an underlying asset and serves as an umbrella term that includes Exchange-Traded Funds (ETFs), Exchange-Traded Commodities (ETCs), Exchange-Traded Notes (ETNs), and US Grantor and other statutory trusts (Fassas, 2012).

Figure 4.8 shows a breakdown of the historical platinum demand for investment purposes from 2004 to 2013. In Figure 4.8, aside from the significant growth in demand noted over the decade, it is also striking that there is no clear trend in geographical regions that dominate platinum demand for investment purposes. For example, in 2008 Japan dominated demand (69%), followed by dominance by Europe in 2009 (58%) and North America in 2010 (71%). Further, it can be noted that no investment in platinum takes place in China. Finally, platinum demand by the investment sector increased by 68 per cent from 2012 to 2013 and demand was not dominated by Japan, Europe or North America for the first time since 2004. The surge in demand in the "Rest of the world" category is attributable to the launch of Absa's Platinum ETF in April 2013 in South Africa (South African Chamber of Mines, 2015). Absa's Platinum ETF became the largest of its kind globally, in terms of volume, just 4 months after its launch.

The rarity of platinum, its use in several industrial applications and the limitations to substitution with other materials in most industrial applications (Nassar, 2015), means that platinum demand is not likely to receed excessively

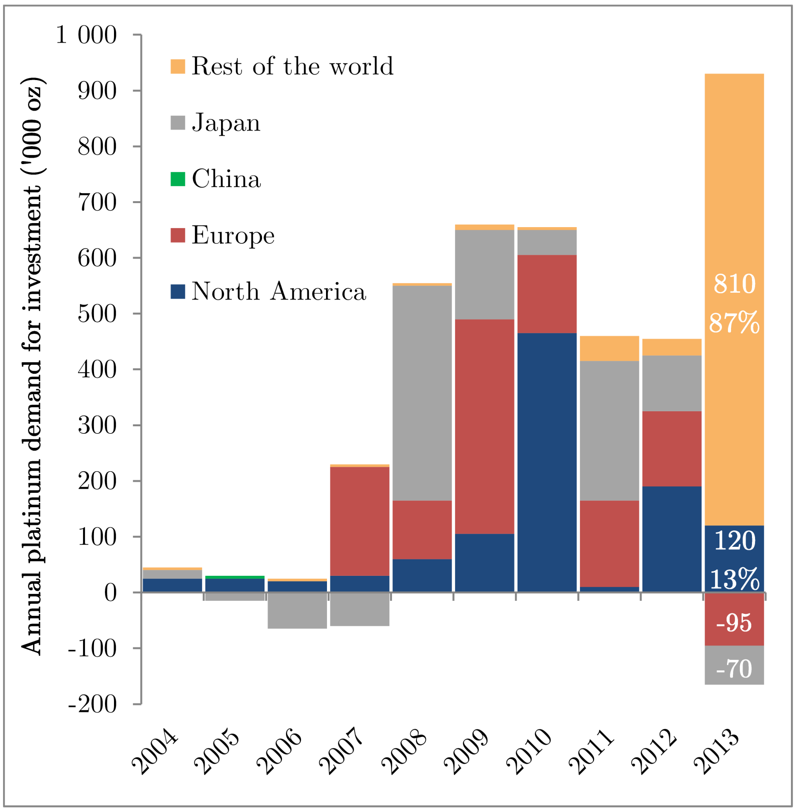


Figure 4.8: Annual gross platinum demand and recycling for investment (values given in thousands of troy ounces) (Johnson Matthey, 2014)

in the foreseeable future. It can therefore be inferred that platinum will remain popular in the commodity investment sector as long as prices are reasonable. Nassar (2015) reported that platinum demand elasticity was low for all applications, except investment and therefore excessive escalation in platinum price will likely have a significant negative impact on platinum demand by the investment sector.

4.2.2.4 Industrial catalysts

Nakamura and Kootungal (2007) reported that the world catalyst market was estimated to be worth more than $12.2 billion in 2006 and that demand was expected to continue to grow as global drive toward more energy efficient processes and products is sustained. Precious metals, due to their unique chemical properties, are widely used as catalysts. Parmon *et al.* (2010) reported that 40 to 45 per cent of catalysts produced globally contained precious metals, most often platinum or palladium.

Platinum catalysts are used in several processes, including petroleum refining, nitric acid production and the production of speciality silicones. In petroleumm refining, platinum can be used as catalyst in isomerisation processes and as the catalytic material that promotes hydrogenation and dehydrogenation in reforming processes (Gary and Handwerk, 2001). Platinum-rhodium or platinum-palladium-rhodium catalyst gauzes are used in the production of nitric acid by oxidation of ammonia. Platinum is typically consumed at a rate of 0.04–0.3 g/t nitric acid produced, depending on the pressure used in the process (Sadykov *et al.*, 2000; Yuantao and Zhengfen, 1999). Silicon compounds are mainly synthesised by room temperature or high-temperature vulcanisation reaction, both of which make use of platinum catalysts to catalyse the reaction (known as a hydrosilation reaction and is similar to a polymerisation reaction). The hydrosilation reaction is used to produce cross-linked silicone polymers (Marchi *et al.*, 2015; Lewis *et al.*, 1997).

The chemical and petroleum industries accounted for 6 per cent and 2 per cent of global platinum demand in 2013, respectively (refer to Figure 4.4, above). Further, from Figure 4.5 it can be noted that the platinum demand by the chemical industry grew from 325 000 oz in 2004 to 540 000 oz in 2013 (66%), while the petroleum industry demand grew from 150 000 oz in 2004 to a peak of 240 000 oz in 2008, after which demand declined to 155 000 oz in 2013, as a result of the global economic downturn. The importance of the chemical industry as a consumer of platinum has therefore increased (increase from 4% of global platinum demand in 2004 to 6% in 2013) and will likely continue along this trend.

Figure 4.9 shows a breakdown of global platinum demand by the chemical and petroleum industries in 2013. Platinum demand by the chemical industry was dominated by China, having consumed 24 per cent of global chemical industry demand in 2013, followed by North America and Europe (19% each). The platinum demand by the petroleum industry was dominated by North America (26%), followed by Europe (10%), China (6%) and Japan (3%). Unsurprisingly, the rest of the world accounted for 55 per cent of demand, due to refining of petroleum taking place close to the petroleum resources in the Former Soviet Union, Middle East, Latin America and Africa.

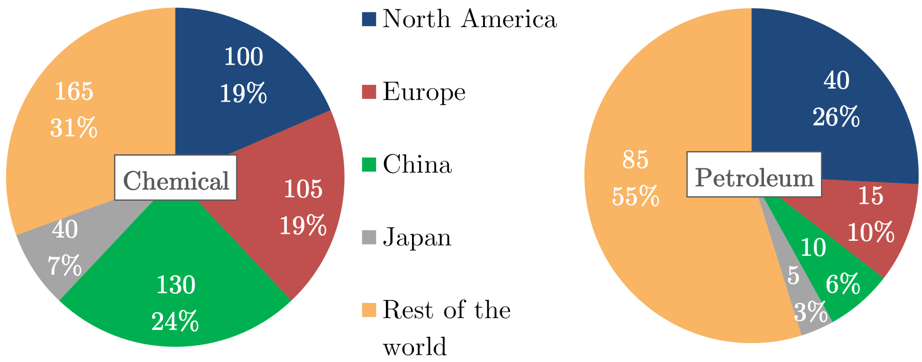


Figure 4.9: Platinum demand for use in industrial catalysts, including the chemical and petroleum industries, in 2013 (values given in thousands of troy ounces) (Johnson Matthey, 2014)

Further, it is important to note that a considerable amount of the precious metals used for industrial catalysts are supplied from secondary sources (i.e. supplied by recycling). Saurat and Bringezu (2008) reported that 33.4 tonnes of the platinum, palladium and rhodium used in the industrial catalyst sector in Europe was from secondary sources, while only 6.5 tonnes was primary inputs. This industry is therefore only a significant consumer of platinum if it continues to grow and consequently its demand exceeds what can be supplied by recycling.

Petroleum remains the most widespread energy source used globally and although continuous effort is being made to decrease global dependence on petroleum by development of renewable alternatives, petroleum is likely to remain an important part of the global energy sector at least until 2050. Use of platinum in this industry will likely decline, but will remain important in at least the medium term. As noted earlier, platinum use in the chemical industry is expected to grow as the industry continues to pursue more energy effective processes and products.

4.2.2.5 Glass industry

Platinum, platinum-rhodium alloys and platinum-gold alloys are widely used in the glass industry as platinum's high melting point and good corrosion resistance makes it suitable for use with the aggressive liquids formed during the high-temperature production of glass. Platinum and platinum alloys, sometimes micro-alloyed with zirconia for increased strength, are used in linings of vessels, surface coatings of ceramics and in equipment parts that contain, channel and form molten glass (Johnson Matthey, 2011; Stokes, 1987).

The manufacture of glass used in thin-film transistor liquid crystal display (TFT-LCD) panels, used in television and computer displays, is the most intensive user of PGMs per unit glass manufactured. Platinum and rhodium linings are used to channel the molten glass in the manufacturing process. Further, bushings[4] used in the production of glass fibre are typically made of platinum-rhodium alloys and represents another one of the largest uses of PGMs in glass manufacturing. Platinum is also used in equipment used for melting, conditioning and forming of optical glass. In this case, rhodium alloys are undesirable as they cause colouration of the glass. Solar glass (used in solar photovoltaic panels) production is a growing user of PGMs and makes use of PGM coatings and fabrications to produce high quality and highly transmissive glass (Johnson Matthey, 2011). Platinum is also used in other glass manufacturing applications, including the production of crystal and tableware glass (Stokes, 1987).

The glass industry represented 3 per cent of global platinum demand in 2013 (235 000 oz) and the demand by this industry has fluctuated significantly over the past decade (refer to Figure 4.4 and Figure 4.5, earlier). The platinum demand by the glass industry fluctuated between a minimum of 10 000 oz in 2009 (representing 0.1% of global platinum demand) and a peak of 515 000 oz in 2011 (6%). High supply from secondary sources resulted in the low demand in 2009. The surge in platinum demand in 2010 was driven by several factors, including a move of customers away from old CRT screen technology, growth in demand for TFT-LCD panels (especially in mobile devices) and recovery of the glass fibre manufacturing industry as the construction sector recovered due to better global economic conditions (Johnson Matthey, 2011).

Figure 4.10, below, illustrates the global platinum demand by the glass industry in 2013. The Chinese glass industry dominated demand, accounting for 58 per cent of global demand. Europe and North America were responsible for 6 per cent and 4 per cent of global demand by the glass industry, respectively, while the rest of the world consumed the remaining 33 per cent. In 2013, the

[4] A bushing is "a vessel with hundreds of precisely dimensioned holes in its base, allowing extremely fine fibres of glass to be consistently produced" (Johnson Matthey, 2011).

Japanese glass industry was a net producer of platinum, with 25 000 oz more platinum produced by recycling of old equipment than was required in new equipment. This illustrates the closed-loop nature of platinum use in the glass industry – Johnson Matthey (2011) reported between 95 and 98 per cent of PGMs used in glass manufacturing can be recovered to be reused, most often again in the glass industry. Saurat and Bringezu (2008) also reported that in 2004, Europe sourced 0.6 tonnes of platinum, palladium and rhodium from primary sources and 49.3 tonnes from secondary sources, further exemplifying the extent to which platinum use in the glass industry forms a closed loop.

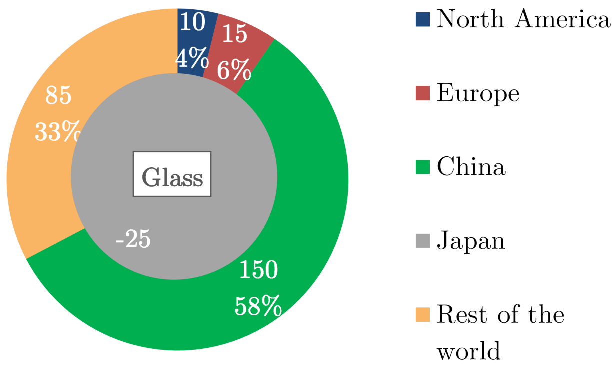


Figure 4.10: Platinum demand for use in the glass industry in 2013 (values given in thousands of troy ounces) (Johnson Matthey, 2014)

Use of PGMs by the glass industry is sustainable, largely due to the closed loop use of PGMs in the industry and the prospect of sustained demand for the various forms of glass. Further, demand for electronic displays is expected to continue to grow and, as a result, growth is expected in the PGM demand of the global glass industry. Iridium is a suitable substitute for platinum in the glass industry, however, large scale substitution of platinum with iridium is unlikely due to the large volumes of the metal required (Nassar, 2015).

4.2.2.6 Medical and biomedical applications

PGMs are widely used in medical, biomedical and dental applications. Platinum and platinum alloys are uniquely suitable to several medical applications due to its low corrosivity, high biocompatibility and good mechanical strength. Further, platinum is a good conducter of electricity, is radiopaque (therefore clearly visible in X-ray images) and can be fabricated into very small, complex shapes (Cowley and Woodward, 2011). Finally, platinum's high melting point and low thermal expansion makes it ideal to be used as alloying element in the dental sector (Givan, 2007). This section only presents a brief overview of platinum use in medical, biomedical and dental applications and the reader is kindly referred to Cowley and Woodward (2011) and Givan (2007) who present complete summaries of the use of platinum in medical applications and the use of precious metals in dentistry, respectively, if more in-depth discussions are sought.

Platinum alloys have long been used in the electrodes of artificial pacemakers and implantable cardioverter defibrillators (ICDs) that are commonly implanted in patients suffering from cardiac rhythm disorders. Platinum is also widely used as marker bands and guidewires for catheters (used in the diagnosis and treatment of, amongst others, heart disease), utilising its radiopacity to allow tracking of progress during minimally invasive treatments. Uses of platinum in the medical industry developed more recently include the use of platinum in stents (used to prop open narrowed arteries) and in components used in neuromodulation devices (delivers electrical impulses to nerves, similar to heart pacemakers). Presently, neuromodulation is not widely used, but it is expected that its use will increase significantly in coming years. Platinum is further also used to sheath irradiated iridium wire used in radiation cancer therapy and in platinum wire coils used to treat aneurysms. Finally, the ability of platinum, in some chemical forms, to inhibit division of living cells, means it is used in anti-cancer drugs to treat testicular, ovarian, breast and lung cancer (Cowley and Woodward, 2011).

In dentistry, platinum is used as a substrate for porcelain densification and is a common component used in precision prosthetic attachments, including full-metal and ceramometal applications. Platinum or palladium is used to reduce the thermal expansion of a precious metal alloy if used in ceramometal bonding with dental porcelain, such that the thermal expansion of the alloy is similar to that of the porcelain (Givan, 2007). Platinum is typically used in gold-palladium-platinum or gold-platinum alloys, however, these alloys have low sag resistance which limits their use. Recently, 1 or 2 per cent gold or platinum has been included in palladium-cobalt alloys by some manufacturers, in an attempt to improve the alloy grain structure (Roberts *et al.*, 2009).

The combined demand of the medical, biomedical and dental sectors (referred to as 'Medical' in all figures) amounted to 3 per cent of global demand in 2013 (refer to Figure 4.4). Upon inspection of Figure 4.5, it can be noted that platinum demand by the these sectors was very consistent throughout, accounting for about 3 per cent of demand throughout the period 2005 to 2013[5]. Demand reached a peak of 3.7 per cent (250 000 oz) in 2009, after which it declined to 2.8 per cent (235 000 oz) in 2013.

[5]Demand by the medical, biomedical and dental sectors was included in the 'Other' category before 2005.

Figure 4.11, below, illustrates the combined global use of platinum in the medical, biomedical and dental sectors. Europe and North America clearly dominate global demand in these sectors, accounting for 38 per cent and 36 per cent of demand, respectively. Japan and China accounted for 9 per cent and 6 per cent, respectively, while demand in the rest of the world accounted for the remaining 11 per cent. The dominance of European and North American platinum demand in these sectors is indicative of the high levels of healthcare and medical technology available in these regions. However, upon inspection of historical data, it is noted that platinum demand by the European and North American medical industries have declined slightly from peak demand levels, while demand in China and the rest of the world grew slowly, but consistently. Demand in Japan remained consistent over the decade under consideration. These trends seem to be indicative of the continuous effort, and progress, being made to bring more and better healthcare to developing countries.

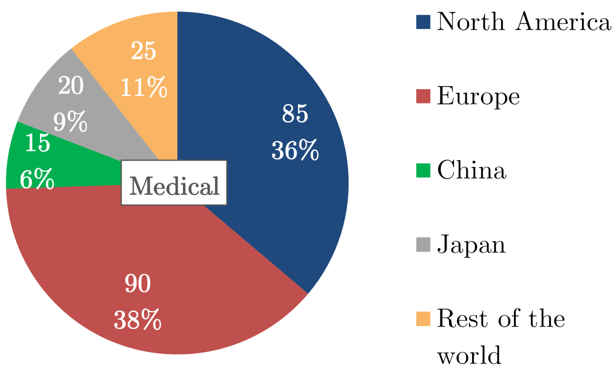


Figure 4.11: Platinum demand for use in medical and biomedical applications in 2013 (includes medical-, biomedical- and dental sectors, values given in thousands of troy ounces) (Johnson Matthey, 2014)

Healthcare demand for platinum is expected to continue to grow as the world population grows and global life expectancy increases (as medical technology advances and healthcare becomes more widely available in the developing world) (Cowley and Woodward, 2011). Large scale substitution for platinum in this industry is unlikely due to the unique useful characteristics of platinum and therefore the medical, biomedical and dental sectors are expected to be sustainable users of platinum.

4.2.2.7 Electrical and electronic components

PGMs are widely used in the electrical and electronics sector – platinum and rhodium are mainly used in electrical applications, while iridium, palladium and ruthenium are primarily used in electronics (where PGMs have substituted gold since 1984). In 2004, the United States Geological Survey (USGS) reported the major uses of platinum in the electrical and electronics sector to include usage in computer hard drives, fuel cells and thermocouples (leading use of platinum in this sector). Further, platinum-rhodium alloys are widely used as electrical resistance heating elements, including typical uses such as cigarette lighters, hot wire ignition systems and sealing devices (United States Geological Survey, 2004).

The electrical and electronics sectors have traditionally been only minor consumers of platinum, accounting for 2.4 per cent of global platinum use in 2013 (refer to Figure 4.4). Platinum consumption by these sectors have also decreased slightly over the past decade (refer to Figure 4.5), declining from a peak of 4.6 per cent of global platinum demand in 2006 to a minimum of 2.1 per cent in 2012. The decreased use of platinum is due to a combination of factors, including economic uncertainty in several key markets and decreased personal computer sales (largely due to increasing computing power of devices such as smart phones and tablets) (Johnson Matthey, 2013). Recycling of platinum from electrical and electronic components also grew significantly over the latter part of the decade under consideration, increasing from zero platinum from recycling in 2007 to 25 000 oz in 2012 (note that this is not clear in Figure 4.5 due to the small amount of recycling from these sectors relative to other sectors). Johnson Matthey (2013) reported that in 2011, only China and Europe recycled electronics to a significant extent, each having produced 5000 oz of platinum from recycling of electronics. The increasing amount of electronic waste generated globally is a widely discussed issue and much research effort is focussed on finding effective ways of recycling this material. The recycling contribution from the electrical and electronics sectors is therefore expected to continue to grow.

Figure 4.12, below, illustrates the global demand for platinum by the electrical and electronics industries in 2013. Demand was well spread, with China once again dominating demand. China accounted for 15 per cent (30 000 oz) of global demand, followed by Japan (25 000 oz, 12%), North America and Europe (both 20 000 oz, 10%). The rest of the world accounted for 54 per cent (110 000 oz) of global demand in these sectors.

The use of platinum in hard disk drives has traditionally formed an important part of platinum demand by the electronics industry, but the hard drive sector is coming under threat from the increased use of solid state drive (SSD) technology which does not require the use of PGMs. The growing business storage sector, however, still results in growth of the hard drive sector. It is further also not expected that SSD technology will completely replace hard drive technology for many years to come, with hybrid drives likely to be com-

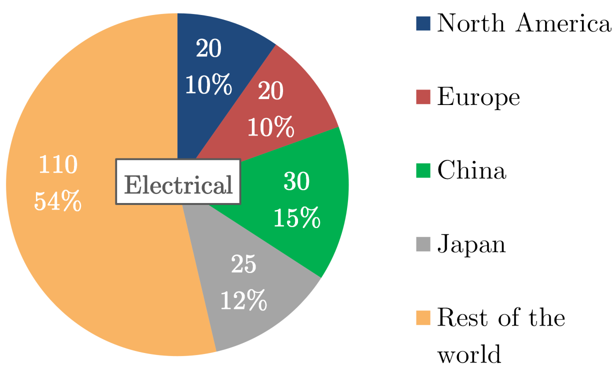


Figure 4.12: Platinum demand for use in electrical components in 2013 (values given in thousands of troy ounces) (Johnson Matthey, 2014)

mon (Johnson Matthey, 2013).

The mass producing nature of the electrical and electronics industry means that small savings on components can eventually amount to significant total cost reductions and therefore the relative prices of the precious metal constituents (PGMs, silver and gold) is a contributing factor to the extent to which they are used. In this sector, emphasis is placed on increasing substitution flexibility to allow the cheapest and most easily attainable metal(s) to be used, thereby reducing cost. However, although per unit consumption of precious metals may decrease, this is generally offset by the greater number of total units produced (United States Geological Survey, 2004).

4.2.2.8 Fuel cells

Fuel cells make use of hydrogen (H_2) and oxygen (O_2) to produce electricity by an electrochemical redox reaction, with water vapour as a reaction product. Platinum, deposited on the electrodes, acts as a catalyst and is required for efficient working of most types of fuel cells by increasing the rate of the electrochemical reaction (Sopian and Wan Daud, 2006; Spiegel, 2004).

Due to extensive research, fuel cells have developed to a point where the technology is effective, long lasting, quiet and reliable. These properties, along with the fact that water vapour is the only waste product produced by its operation, if hydrogen is used as fuel, make fuel cells ideal to power vehicles or to provide an uninterrupted power supply for organisations such as hospitals and mines. Use of fuel cells to replace rechargeable batteries in portable electronic devices is also being investigated (Wilburn and Bleiwas, 2004).

Fuel cells have not yet seen commercial deployment due to the high production cost, which is largely due to high platinum content and the lower cost of competing energy sources. Significant research focus has been on reducing platinum requirements in order to make fuel cells more affordable. With regard to fuel cell vehicles (FCVs), the International Platinum Association (IPA) estimates that a commercially viable FCV would use about 6 to 7 grams of platinum, slightly more than current use in a catalytic converter. Commercial use of fuel cells in fuel cell vehicles is further impaired as such use requires safe and efficient production, transport and storage of hydrogen gas, which remains a problem (Wilburn and Bleiwas, 2004).

However, Jones and Botha (2014) reports that in their research, carried out since 2011, they found that the development of fuel cell technology was increasing and that the case for the use of fuel cells was strengthening. They report that fuel cells are likely to become an important element of the global energy infrastructure, including use in vehicles and on- and off-grid energy generation, in 20 to 30 years. The prohibitively high cost of fuel cells is expected to be addressed by, amongst others, economy of scale and improved design as the fuel cell industry grows within a few years. This expected growth will result in increased use of platinum and puts South Africa, with its extensive platinum resources, in a very favourable position. Jones and Botha (2014) argue that development of the industry is at such a stage that a window of opportunity exists for South Africa to establish a presence in the fuel cell industry. However, in order to achieve this, significant ground is yet to be covered in terms of product development, infrastructure development (especially fuelling infrastructure), market development (creating awareness) and regulation and standards development.

The South African government has recognised this potential and, through its National Hydrogen and Fuel Cells Technologies (HFCT) Research, Development and Innovation Strategy (branded Hydrogen South Africa or HySA), is aiming to exploit the opportunity by investing in beneficiation research regarding, amongst others, fuel cell innovation (Bessarabov *et al.*, 2012; Jones and Botha, 2014). Three Centers of Competency (CC), namely: Hydrogen Catalysis CC, Hydrogen Infrastructure CC, and Hydrogen Systems CC, was established to facilitate the development and innovation required to achieve the goals of the national strategy (Bessarabov *et al.*, 2012).

Further, two of the major producers of PGMs in South Africa, Anglo American Platinum (Amplats) and Impala Platinum (Implats), are investing extensively in fuel cell technology and its development. Amplats launched the world's first fuel cell mini-grid electrification field trial on 5 August 2014 in a small community in the Fezile Dabi District of the Free State Province in South Africa. The trial ran for 12 months and provided electricity for 34 households

(Anglo American Platinum Ltd., 2014). Implats announced on 1 April 2015 that it is planning to use fuel cells to provide energy for its PGM refinery in Springs, east of Johannesburg, from early 2016 (Impala Platinum Ltd., 2015).

The global development of fuel cells and the so-called Hydrogen Economy is well under way, however, very few companies are selling commercial fuel cells. 4th Energy Wave (2016) reports that of the more than 200 fuel cell stack and system companies, only about 30 are selling fuel cells commercially, with less than 60 additional companies close to the point where they will start selling their products commercially. Significant investment and development is therefore still required in the fuel cell industry. Further, 4th Energy Wave (2016) reports that Japan, followed by South Korea and Germany, are the most attractive countries to export fuel cells to or sell into as a local market. South Africa ranks as the 11th most attractive, making it clear that South Africa has a long way to go to become a significant player in the global fuel cell industry.

4.2.2.9 Other applications

Platinum is used in a variety of minor applications not included in the preceding sections. These include the use of platinum in sensors, automotive spark plugs and turbine blades.

In sensors, platinum is widely used to measure poisonous carbon monoxide and nitrogen oxide concentrations. Such sensors are used in vehicle climate control systems, as well as carbon monoxide detectors in buildings. Further, the use of platinum-tipped electrodes in spark plugs is increasing as platinum-tipped electrodes are more durable than base metal electrodes. Finally, platinum pinning wire is used to hold moulds in place during the casting of hollow core turbine blades. Modern turbine blades to be used in the high pressure section of turbines are also often coated with a platinum aluminide coating to extend the life of the blades. The use of platinum in turbines is expected to grow (Johnson Matthey, 2006).

4.3 Choice of specific platinum beneficiation industries

Many of the industries discussed in Section 4.2.2 are suitable to be used as case study industries to test the utility of the framework. The catalytic converter industry is especially well suited as it is the largest platinum consuming industry globally and a catalytic converter manufacturing industry is already established in South Africa. Numerous companies are therefore active in the international and national catalytic converter industries and subsequently a large amount of relevant and suitable information is available for these industries. The importance of the automotive industry in South Africa, including the catalytic converter industry, is recognised at policy level in South Africa and continued development of these industries forms part of the Department of Mineral Resources' (DMR) Beneficiation Strategy (South African Department of Mineral Resources, 2011). The catalytic converter industry will therefore be the first industry used to test the utility of the framework in this project.

The platinum jewellery industry is the second largest consumer of platinum globally and therefore has advantages similar to those of the catalytic converter industry in terms of availability of information. Further, beneficiation of gold and diamonds by use in jewellery fabrication has been identified as one of the target value chains of the DMR's Beneficiation Strategy, with "Integrated Jewellery Hubs" to be established throughout the country. The Beneficiation Strategy further states: "Although the fabrication of platinum jewellery is not a priority area for platinum group metals (PGM) beneficiation, the integration of specialised platinum jewellery facilities into any of the jewellery hubs would be well received" (South African Department of Mineral Resources, 2011). The platinum jewellery industry will therefore be the second industry used to test the utility of the framework in this project.

Finally, with the significant global emphasis on fuel cells as part of the global energy mix of the future and the potential for establishing a fuel cell industry in South Africa, the fuel cell industry would have been a relevant industry to use to test the utility of the framework. However, the authors could find no suitable company that produces fuel cells and makes use of the GRI Sustainability Reporting Guidelines. The appropriate information was therefore not available in the correct form and the fuel cell industry was not used as a case study. This problem may be expected to dissipate as more fuel cell producers enter the global market and report their sustainability performance according to the GRI Sustainability Reporting Guidelines. Further, it is worth noting that with all the research attention currently devoted to fuel cells and the fuel cell industry globally, it might have been possible to collect the required data from sources other than company annual reports. However, collecting data from such sources would inherently take longer and would likely require more alterations to the data to make it appropriate to use in the framework. It was therefore deemed outside the scope of the present investigation to attempt to collect the required data in this way.

4.4 Chapter 4: Conclusion

This chapter introduced platinum beneficiation as the case study used to test the utility and shortcomings of the developed framework and the motivation for this choice. An overview of the global platinum value chain was then presented to provide the reader with background of the value chain and motivate why the catalytic converter industry and the platinum jewellery industry were chosen as case study industries to be compared by using the framework. The next chapter describes the application of the framework to these case study industries.

Chapter 5

Case study: Application of the framework

The previous chapter presented the first part of phase 3 of the framework development methodology (as presented in Figure 3.2 in Chapter 3). In that chapter, the beneficiation of platinum was introduced as the case study that was chosen to assess the potential utility and shortcomings of the framework. This chapter continues from that starting point and presents the remainder of phase 3.

The collection and scaling of the data used in the framework are discussed in Sections 5.1 and 5.2, respectively. Section 5.3 then discusses the uncertainty analysis conducted in order to quantify the influence of input uncertainty on the final results generated by the framework. The results generated by applying the framework to the case study industries are then discussed in Section 5.4. The chapter is concluded with a brief discussion (at the hand of a S.W.O.T. analysis) of the author's impressions of the utility of the framework based on its application discussed in preceding sections.

5.1 Data collection

As introduced in Section 3.3.1, the present framework makes use of data reported by organisations in relevant industries abroad to objectively compare the potential of developing these industries in a target country. The GRI G4 Sustainability Reporting Guidelines are used as the basis for the present framework. The catalytic converter industry and the platinum jewellery industry were chosen to be used as case study industries, as discussed in Section 4.3. This section therefore discusses the selection of appropriate organisations to be used to represent the case study industries and the collection of data from the annual publications of these organisations. The identities of all organisations will be kept anonymous.

The global catalytic converter industry, having been the largest consumer of platinum for some time now, is composed of a large number of organisations. Some of these organisations make use of the GRI reporting guidelines, leaving the user of the framework with a few suitable candidate organisations that can be used to represent the catalytic converter industry. The author decided to use one of the largest global producers of catalytic converters as the subject whose data will be used. This organisation is globally acclaimed and has been publishing sustainability reports since 2008. The organisation further also has operations in more than 30 countries, which was considered an advantage as country- or region-specific effects in the data will be more balanced and therefore less pronounced, making the data more generic and likely more accurate, irrespective of the target country.

The platinum jewellery industry is the second largest consumer of platinum globally and therefore, again, a large number of organisations are active in this industry. The number of organisations that can potentially be used to represent the jewellery industry is, however, considerably reduced as many of these organisations do not publish sustainability reports (typically privately owned companies) or do not make use of the GRI reporting guidelines. The author once again selected one of the leading global platinum jewellery manufacturing organisations to represent this industry. This organisation is well-known and has operations in 25 countries, which is once again seen as an advantage.

Large, pace-setting organisations were chosen to represent the case study industries in this study as this ensures a best-case comparison (or close to, at least), making the results of the comparison more conclusive. If an industry is superior to another in some dimension, based on the best-case scenario for both industries, little doubt can exist that that industry is indeed superior to the other (in general).

Having chosen the organisations that were used to represent the catalytic converter industry and the platinum jewellery industry, the author proceeded to collect the required data from the organisations' annual financial and sustainability reports. 2014 was used as the subject year for all data and calculations as this was the latest year for which sufficient data could be obtained when the case studies were performed. Note that the application of the framework discussed here made use of the high level scope of all indicators and the framework was not tested with the scope of indicators defined for a more detailed assessment (refer to Section 3.3.3 for a discussion of the scope of indicators).

The data collection process was complicated in several ways. The first problem was that different organisations used different methodologies to calculate some of the indicator values, although this was not a great concern for the most part as the GRI indicators are generally well-defined. A much more pronounced problem was the fact that most organisations do not report all the indicators that form part of the GRI reporting guidelines. Organisations typically only report indicators that have been found material to their specific operations, while some also exclude indicators that are not measured adequately for their operations, or indicators that disclose information that is considered proprietary. As a result, data could not be found for some indicators used in the framework, as summarised in Table 5.1. Table 5.1 also indicates whether or not the indicator was reported by each organisation representing an industry.

Table 5.1: Indicators for which data was not reported by one or both of the organisations representing the case study industries

Indicator ID and description		**Catalytic converter industry**	**Jewellery industry**
Envi-1.1	Materials by weight	No	No
Envi-1.2	Water withdrawals by weight	Yes	No
Envi-3.2	Greenhouse gas emissions (Scope 3)	Partially	No
Envi-4.1	Water discharge	Yes	No
Envi-4.2	Waste by type	Yes	No
Envi-5	Products and packaging material reclaimed	No	No
Soci-3	Average hours of training for employees	Yes	No

The analysis and imputation of missing data is an extensive and rapidly developing research field, with several implicit (replacing missing values by those from related data sets) or explicit (statistical modelling) imputation techniques that can be used to estimate missing indicator values. However, the imputation of data will always affect the accuracy and the credibility of the composite indicator(s) in which that data is used (OECD and European Commission, 2008). For the present investigation, imputation of missing indicator values was not considered due to several reasons. Firstly, no data could be found for the missing indicators, although extensive effort was made to find such data in industry reports and annual reports by similar organisations. This meant that neither explicit nor implicit modelling could be used to estimate missing values. Secondly, the potential inaccuracy of using imputed data was considered larger than the inaccuracy introduced by exclusion of these indicators. Most of the indicators excluded from the framework due to lack of data were sub-indicators used in conjunction with others to describe a specific aspect. The exclusion of these sub-indicators does therefore not result in the complete neglect of that aspect, although that aspect is less fully described. In contrast, indicators Envi-5 and Soci-3 were both stand-alone indicators used to measure the percentage of products and packaging materials reclaimed and the average hours of training employees receive, respectively. Exclusion of these indicators thus means that these aspects are no longer considered in the framework and this is a considerable drawback. The expected increase in the availability of sustainability data in the future would hopefully make this type of occurrence less prevalent. Note that the indicators for which data could not be found were still included in the uncertainty analysis to account for the effect of the missing data (as described in Section 5.3).

5.2 Scaling of data

The data collected for each organisation, as described above, had to be scaled in two ways. Firstly, neither of the organisations used to represent the case study industries in this study were active in only the subject industries. Their operations spanned several industries and as a result the total values reported for all their operations had to be adjusted to only represent the relevant portion of their operations. Then, secondly, this data had to be scaled from organisation- to industry-level, such that the data represent an entire industry and not only a single organisation in that industry.

The first scaling for both industries was based on the percentage of total sales contributed by the relevant portion of the organisation's operations. The organisation representing the jewellery industry reported that platinum was used in two of its product categories: 87% of statement, fine and solitaire jewellery were made of platinum and 92% of engagement jewellery and wedding bands were made of platinum. The sales reported for these categories were therefore scaled by 87% and 92%, respectively, and summed to attain an estimate of the sales revenue generated by the sale of platinum jewellery pieces. This amounted to 46% of the total sales reported by the organisation (see calculations given by Equations C.1 through C.4 in Appendix C). All subsequent indicator values that were dependent on organisation size, for example greenhouse gas emissions or number of employees, were therefore scaled by this 46%. This scaling is, of course, based on the very crude assumption that the scaled indicator values are directly and linearly related to sales revenue. At the lack of any better, easily attainable, scaling parameters, this assumption was nonetheless used, but the percentage value was varied uniformly by 10% in either direction (i.e. 36% to 56%) in an attempt to account for the uncertainty in this assumption.

Similarly, the organisation representing the catalytic converter industry reported that its catalytic converter segment generated 56% of the organisation's sales revenue. This percentage, subject to the same assumption, was again used to scale the indicators as required and it was, similar to the above variation, uniformly varied between 46% and 66% to account for the uncertainty in the assumption of a directly proportional relationship (the uncertainty analysis is described in the next section).

The second scaling of the data – from organisation- to industry-level – was performed using two different methods. The annual sales revenue generated by the global platinum jewellery industry is not freely available and there is little consensus over the exact amounts in the few industry reports that report sales figures. On the other hand, data on the mass of platinum used annually for jewellery purposes is easily attainable (see Johnson Matthey (2014) for example). As a result, it was decided that the annual mass of platinum used by the organisation representing the jewellery industry would be used to scale its data. However, the organisation does not report its annual use of platinum and therefore an estimate had to be calculated. This calculation involved dividing the total sales revenue generated by the sale of platinum jewellery pieces by the average price per piece (as reported) to obtain an estimate of the number of jewellery pieces sold. This number could then be multiplied by an estimate of the mass of each jewellery piece to obtain an estimate of the total amount of platinum used for the year. Anglo American Platinum Ltd. (2016) states that the average mass of platinum in a typical platinum jewellery item is about 4 grams. In personal correspondance with the author, an industry expert stated that the average mass of platinum per jewellery item is typically about 4 to 8 grams, noting that a wedding band typically contains 8 grams of platinum, while a pair of earrings usually contains a maximum of about 20 grams of platinum. Therefore, in the present investigation, 6 grams was used as an estimate of the average amount of platinum used in a typical platinum jewellery item. To account for the uncertainty in this estimate this value was varied according to a triangular distribution between 0 and 20 grams in the uncertainty analysis, as presented in Section 5.3. A 5% loss of metal mass during fabrication was included in the calculation of the total amount of platinum used by the organisation and this 5% was also varied in the uncertainty analysis. According to these calculations, the mass of platinum consumed by the organisation amounted to about 3.3% of global platinum use for jewellery purposes in 2014. Assuming a platinum jewellery industry consuming 5% of global platinum demand for jewellery purposes can be established in South Africa, all indicator values were scaled by 1.52 ($5 \div 3.3$) to represent an industry. The assumption that a platinum jewellery industry consuming 5% of global platinum demand for jewellery purposes can be established in South Africa is completely arbitrary and was varied uniformly between 3 and 7% in the uncertainty analysis. Section 5.4 will later show that this arbitrary assumption of 5% has little influence on the conclusions that can be drawn from the comparison. All the calculations described here are presented in detail in Section C.3 in appendix C.

The scaling for the catalytic converter industry was simpler, as the catalytic converter industry is already established in South Africa and therefore data of the revenue generated by the export of catalytic converters is readily available. For the scaling in this case, the value of total exports of catalytic converters from South Africa for 2014 as reported by the Automotive Industry Export Council (2015) was used in conjunction with the total revenue generated from sales of catalytic converters calculated for the organisation. As shown by Equation C.33 in Appendix C, the catalytic converter exports from South Africa was about 31.2% of the value of sales of catalytic converters by the organisation. To represent an industry, all relevant indicators values for the organisation were therefore scaled to 31.2% of their original values. Note that only revenue generated from export of catalytic converters was used as the local consumption of catalytic converters is small compared to exports (less than R800 million, compared to about R20 billion generated by exports).

5.3 Uncertainty analysis

Various factors can influence the uncertainty associated with the outputs generated by application of the framework. Sources of uncertainty in the present investigation can be divided into two categories. Firstly, there is uncertainty related to the data used in the framework. This refers to the embedded uncertainty in the input data, as well as the uncertainty related to assumptions and estimates made in the calculation and scaling of the input data. Secondly, uncertainty is introduced with the choice of specific construction for the framework, i.e. the selection of indicators, weighting, normalisation and aggregation schemes. Uncertainty analysis is therefore required to quantify all these uncertainties and thereby allow the user to take these into account when drawing conclusions from the framework outputs.

The uncertainty analysis conducted for the present investigation, as described in this section, only pertains to the first category of uncertainty. As discussed in Chapter 3, the choice of weighting, normalisation and aggregation scheme for the framework was well informed and the best suited methods were used in the framework. The use of weighting schemes other than equal weighting are either fundamentally flawed (in the context of the present investigation, at least) or are participatory in nature and thus requires the collection of empirical data (which is difficult seeing that the industries investigated with the framework are most often not yet established in the country where the comparison is conducted). Similarly, using NCMC aggregation is an obvious choice due to its non-compensatory nature, which is a very important requirement when comparing sustainable development options. Therefore, although the results generated by the framework may differ with a different combination of weighting, normalisation and aggregation schemes, this was not analysed in the uncertainty analysis.

Monte Carlo simulation, using the @Risk® extension for Microsoft Excel, was used to conduct the uncertainty analysis. Ten thousand iterations of random input values were used. Appendix D presents a complete list of all the input values that were varied, along with specifications of the probability distribution functions used and the results of the simulation. Uniform distribution functions were used for indicator values that the author considered very uncertain, while triangular distributions were used for indicator values for which clear minimum and maximum values existed. All risk and impact scores were varied one point up and one point down from the allocated score in a uniform distribution in which only discrete values were allowed (for example, a score of 5 was varied uniformly between the discrete values 4, 5 and 6).

The indicators for which no data could be found, listed in Table 5.1, were also included in the uncertainty analysis. As any of the two industries could be superior in terms of these indicators, the values were varied from the jewellery industry being superior to equal performance by both industries to the catalytic converter industry being superior. To illustrate, consider indicator Envi-1.1 which is one of 3 sub-indicators, each weighting one third, of which indicator Envi-1 is composed. In the uncertainty analysis, the jewellery industry had equal probabilities of being superior to (receiving a score of 1/3), equal to (receiving a score of 1/6) and inferior to (receiving a score of 0) the catalytic converter industry in terms of indicator Envi-1.1. The catalytic converter industry was constrained to receive the symmetrical opposite score of the jewellery industry such that the two scores sum to a total of 1/3 (if the jewellery industry, for example, receives a score of 1/3, the catalytic converter industry receives a score of 0). As such, all possible outcomes were accounted for.

5.4 Results

This section presents the results generated by applying the framework to the platinum jewellery industry and the catalytic converter industry. True to the purpose of this chapter, many of the discussions are focussed on evaluating the utility and shortcomings of the framework, although the relevance and implications of the results in the broader context are also discussed.

Figure 5.1 illustrates the outcome of comparing the platinum jewellery industry and the catalytic converter industry by making use of the framework. The catalytic converter industry was found superior in terms of the economic and social dimensions, while it was found inferior in terms of the environmental dimension. The confidence associated with the ranking of each dimension, based on the results of the uncertainty analysis, is also indicated in Figure 5.1.

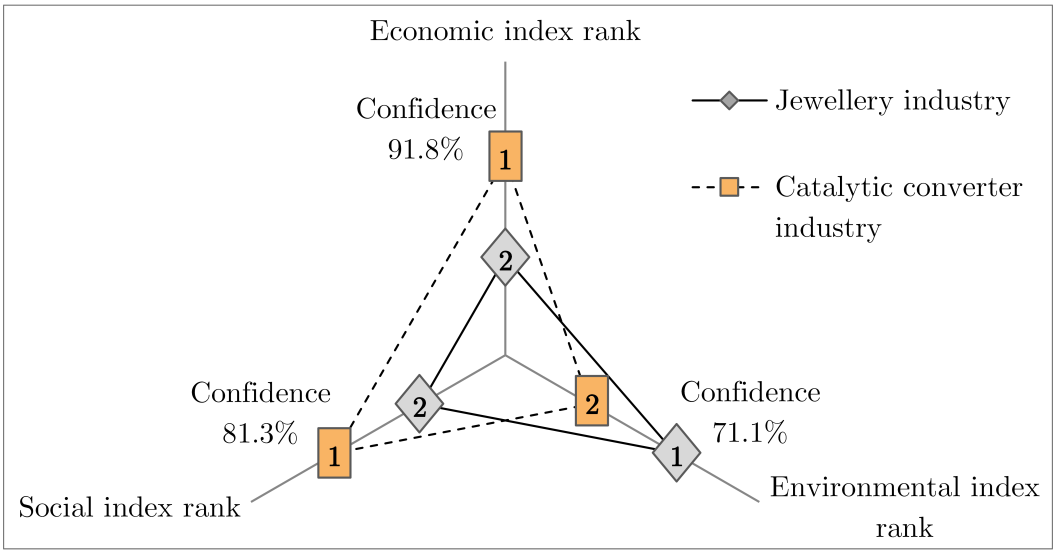


Figure 5.1: Results generated by using the framework to compare the platinum jewellery industry and the catalytic converter industry

Appendix E presents all the static indicator values and the scores each industry received per dimension. As explained in Chapter 3, each dimension was measured with six indicators, each weighing one sixth. The weight of each indicator in which a specific industry is superior is added to its score for that dimension (a total score of one could therefore be attained per dimension). Considering the economic index, the jewellery industry was superior in terms of indicator Econ-1 and the industries were rated equally in terms of indicator Econ-4. The jewellery industry therefore attained a total score of three twelfths ($1/6 + 1/12$), while the catalytic converter industry attained the remaining nine twelfths, or three quarters, of the total. Similarly, the jewellery industry was superior in terms of indicators Envi-1, Envi-2 and Envi-3 and the industries were rated equally in terms of indicator Envi-4. The jewellery industry therefore attained a score of seven twelfths ($3 \times 1/6 + 1/12$), while the catalytic converter industry attained the remaining five twelfths. In the social dimension the catalytic converter industry was superior in terms of indicators Soci-2 and Soci-4, with the industries rated equally in terms of indicators Soci-1, Soci-3, Soci-5 and Soci-6. As such, the jewellery industry attained a score of four twelfths ($4 \times 1/12$), or one third, and the catalytic converter industry attained the other two thirds of the score.

Figure 5.2, on the following page, presents the scores attained by each industry when the uncertainties in the input variables are considered, in terms of the three dimensions of sustainability. The 90% confidence intervals and the static values, when uncertainty is not taken into account, are also indicated. Figure 5.3 then presents a summary of the sensitivity of the jewellery industry index values to variation in input values. The deviation of the mean index value (i.e. the range of mean) as a result of variation in the ten input variables with the largest impact on the mean value, is presented for all three dimensions. As only two industries were compared in this study, the range of mean values for the catalytic converter industry is identical to those of the jewellery industry and is therefore not presented. The complete sensitivity analysis results can be found in Table D.2 in Appendix D.

5.4.1 Economic index

The uncertainty analysis results indicate that the mode and median values for the economic index of the jewellery industry are both 4/12, while the mean value is 0.297. As only two industries were considered in the analysis, the results of the uncertainty analysis for the catalytic converter industry is the symmetrical opposite of that for the jewellery industry: the mode and median values are both 8/12 and the mean value is 0.703. The mode and median values differ from the static values, indicating that the uncertainty in input values causes a slight shift in index value from the static value towards the central value of 6/12 where the economic potential of the jewellery industry is considered equal to that of the catalytic converter industry. However, the 90% confidence intervals of the industries (as illustrated in Figure 5.2) only meet at the 6/12-point and never overlap, which means the likelihood of the jewellery industry surpassing the catalytic converter industry in terms of economic index is very small. As indicated in Figure 5.1, the catalytic converter industry can be considered superior with about 92% confidence.

The superiority of the catalytic converter industry in the economic dimension in the present investigation stems from its strong performance in terms of indicators Econ-2, Econ-3, Econ-5 and Econ-6. These are all indicators that are measured in terms of risk or impact scores and are therefore open to subjectivity introduced by possible bias of the user of the framework. As such, the strength of the catalytic converter industry in the economic dimension in this comparison may be seen as indicative of reality, but the complete accuracy of these results can be confirmed only by consulting relevant experts involved in the jewellery and catalytic converter industries.

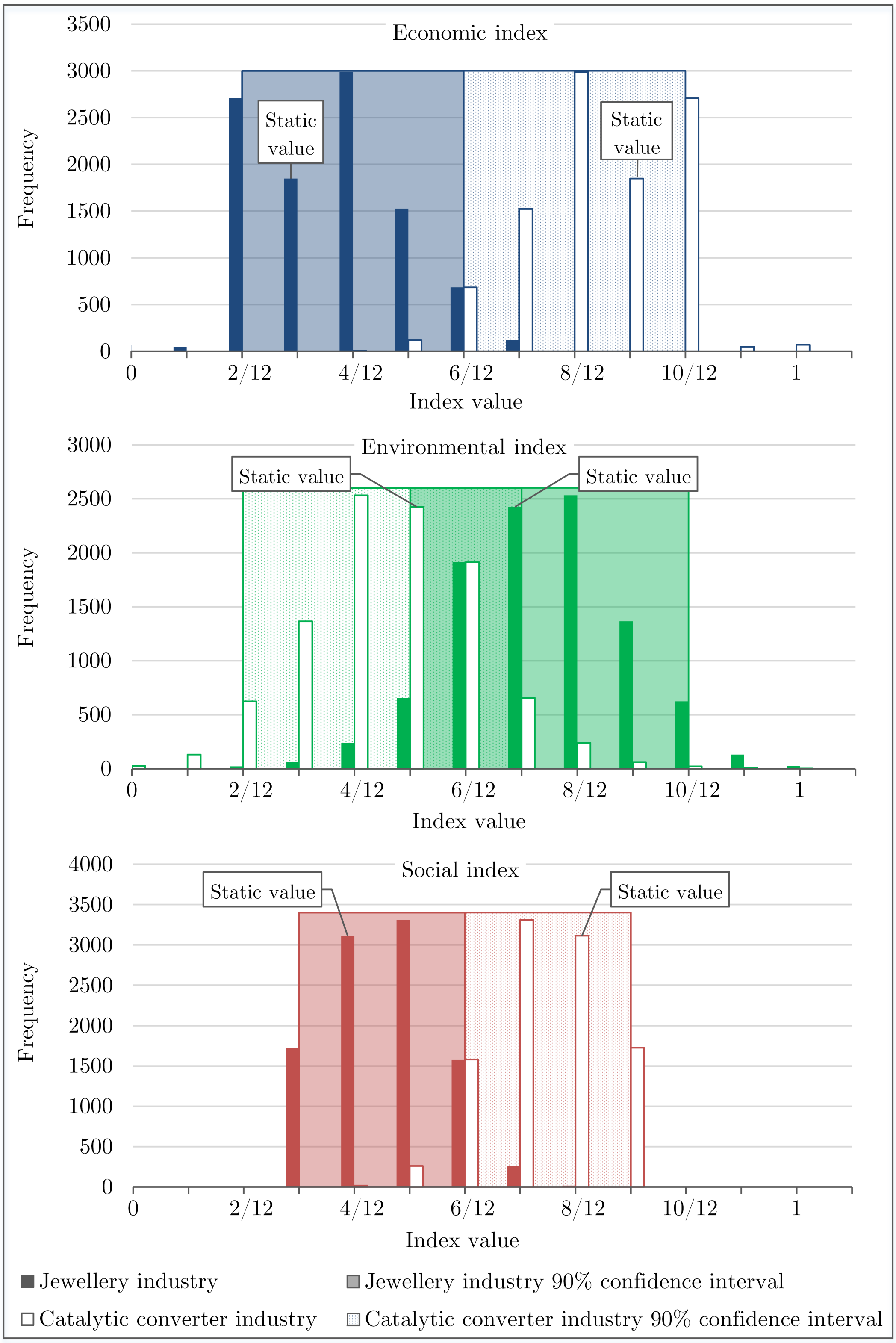


Figure 5.2: Index values and 90% confidence intervals for comparison of the platinum jewellery industry and the catalytic converter industry by using the framework

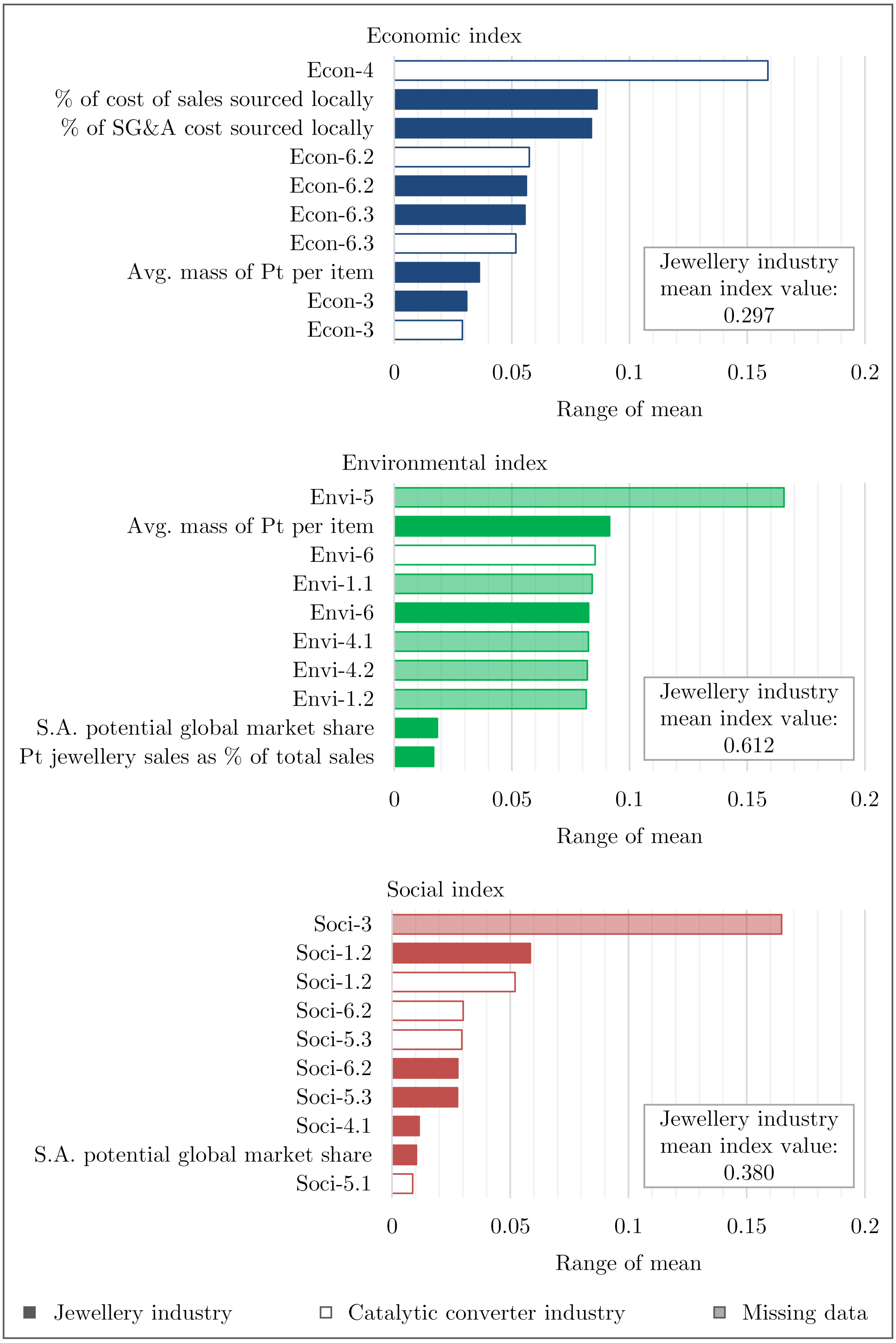


Figure 5.3: Ten input variables varied in the uncertainty analysis that has the largest impact on the mean index value for each dimension

Further, the importance of indicators measured in terms of risk and impact scores implies that the scaling of the data from organisation- to industry-level has little impact on the results for this dimension, as risk and impact scores are considered scale independent. Thus, the jewellery industry is far superior to the catalytic converter industry in terms of expected earnings, but is considered inferior in the economic dimension overall as a result of the relative strong performance of the catalytic converter industry in terms of the risk and impact score-based indicators. This is strongly underpinned by the previously mentioned importance of considering sustainable development as a holistic concept in which non-compensatory logic is essential (see Section 3.3.6). Very strong performance in some aspects cannot offset poor performance in others. The platinum jewellery industry can therefore only become superior to the catalytic converter industry in terms of economic potential if its positive indirect economic impacts become more substantial and the competitiveness of establishing such an industry in South Africa is improved in terms of the factors measured by sub-indicators Econ-5.1 through Econ-5.4. The arbitrary assumption that a jewellery industry consuming 5% of the total platinum consumption for jewellery purposes in 2014 can be established in South Africa is therefore not of significance in the final ranking of the industries in terms of the economic index.

Considering Figure 5.3, it is observed, as would be expected intuitively, that those indicators and sub-indicators in which the performance of both the industries are very similar are the ones with the most significant impact on the index values. A slight change in these indicator or sub-indicator values results in a reversal of the ranks of the industries in that aspect and therefore directly impacts the index value for that dimension. Both industries, for example, are expected to spend about 85% of its operating cost on local procurement (as measured by indicator Econ-4). This value is reported directly for the catalytic converter industry, while it is calculated by using the percentage of cost of sales sourced locally and the percentage of selling, general and administrative (SG&A) cost for the jewellery industry (refer to Equation C.12 in Appendix C). Variation in the percentage values calculated for indicator Econ-4 therefore has a significant impact on the relative performance of the industries in the economic dimension. Similarly, the industries both scored an impact score of 1 for sub-indicators Econ-6.2 and -6.3, resulting in the high impact of these sub-indicators on the economic index value seen in Figure 5.3. Further, as explained in Section 5.2, the average mass of platinum per jewellery item was used in the scaling of the data for the jewellery industry and therefore has a direct impact on the value of Econ-1 (the only economic indicator that is scale dependent). The high impact of this input value on the economic index exemplifies the potential impact that scaling (and incorrect scaling) can have on the results the framework generate. Finally, the jewellery industry received an impact score of 2 for indicator Econ-3, while the catalytic converter industry received a score of 4 for that indicator. As a result, varying these indicator values one point up and one point down in the uncertainty analysis resulted in equal performance (impact score of 3) by the industries in some cases. In such a case, both industries receive a value of 1/12 for this indicator instead of the jewellery industry receiving the total 1/6 and the catalytic converter industry receiving 0. This clearly has an impact on the economic index value.

5.4.2 Environmental index

The static values for the environmental index show that the jewellery industry is considered slightly superior, scoring seven twelfths to the five twelfths of the catalytic converter industry. However, when the uncertainty in the input values is considered, it becomes clear that there is little to choose between the industries in the environmental dimension. The mode and median index values for the jewellery industry are eight twelfths and seven twelfths, respectively, resulting in a mean value of 0.612. This implies mode and median values of four twelfths and five twelfths, respectively, and a mean value of 0.388 for the catalytic converter industry. The index values of the industries are concentrated close to the centre value of six twelfths where the industries are considered to have equal potential. It is therefore no surprise that the 90% confidence intervals of the industries overlap in the region between five and seven twelfths and that the certainty of the jewellery industry being superior in this dimension is only about 71% (as indicated in Figure 5.1).

The slight superiority of the jewellery industry in this dimension is a result of strong performance in indicators Envi-1, Envi-2 and Envi-3. Indicators Envi-1 and Envi-2 measure the material and energy consumption of an industry, respectively, as well as the impact of each type of consumption. Indicators Envi-3 and Envi-4 measure the mass of gaseous emissions and waste discharge, respectively, by an industry. Envi-4 also considers the overall quality of the waste discharged in terms of an impact score. As mentioned in Section 5.1, relevant material consumption and waste discharge data could not be found for the industries considered in the present investigation and indicators Envi-1 and Envi-4 were therefore directly related to the impact scores of sub-indicators Envi-1.3 and Envi-4.3, respectively. As a result of the scale-dependent nature of these indicators (with the exception of Envi-1 and Envi-4 in this case), the scaling of the organisation-level data to industry-level has a significant impact on the performance of the jewellery industry relative to the catalytic converter industry. This is clearly visible in Figure 5.3, where three of the ten input variables with the highest impact on the environmental index are related to the scaling of the data (namely, the average mass of platinum per jewellery item, the potential South African share of the global platinum jewellery market and the sales of platinum jewellery by the organisation representing the jewellery industry as a percentage of its total sales).

Figure 5.3 further also illustrates the significant potential impact that the lack of data for some of the variables has on the value of the environmental index. Five of the ten input variables with the most significant impact on the index value are variables for which data could not be found. The high uncertainty associated with the environmental index values, seen in the wide and overlapping 90% confidence intervals in Figure 5.2, therefore primarily stems from these indicators which, due to the lack of data, had to be varied to account for any outcome. Indicator Envi-6 is the only input value among the ten inputs that has the most significant impact on the environmental index that is not linked to missing data or the scaling of the data. Its high influence on the index value is a result of the similar performance of the industries in terms of the aspect it measures (the potential environmental impacts in the supply chain). The jewellery industry received an impact score of 6, while the catalytic converter industry received a score of 5. These scores overlap when varied one point up and one point down in the uncertainty analysis, thereby directly influencing the index value.

Finally, improved performance by the catalytic converter industry (due to more efficient operation of facilities or due to a smaller industry in South Africa) or poorer performance by the jewellery industry (due to less efficient operation of facilities or due to a larger industry in South Africa) can result in reversal of the index values in this dimension. Rating the industries differently in terms of the indicators quantifying impacts in the form of risk and impact scores, and the availability of data for indicators Envi-1.1, -1.2, -3.2, -4.1, -4.2 and -5, may further affect which industry is deemed superior. Thus, although the jewellery industry is considered superior based on the results of the comparison in this investigation, its superiority is not completely convincing.

5.4.3 Social index

The catalytic converter industry is superior in the social dimension with a static score of eight twelfths, compared to the four twelfths of the jewellery industry. The uncertainty analysis results show that both the mode and median values for the catalytic converter industry are seven twelfths, while the mean value is 0.620. Conversely, the mode and median values for the jewellery industry are five twelfths, and the mean value is 0.380. Similar to the economic dimension, the 90% confidence intervals only touch at the halfway point, indicating that the likelihood of the catalytic converter performing better than the jewellery industry in the social dimension is high (more than 81%, with about a 15% chance of the industries being equal).

The industry scores are once again very close, with the catalytic converter industry gaining its slight advantage with strong performance in indicators Soci-2 and Soci-4. The industries are tied even at the other four indicators (with the exception of Soci-3, for which data could not be found). Indicators Soci-4, -5, and -6, and sub-indicator Soci-1.2 are all based on risk or impact scores and as a result, the subjective perspective of the user of the framework may have had a significant influence on the scores the industries obtained in the social dimension. Further, similar to the economic index, scaling had a minor influence on the results for the social dimension. No data could be found for indicator Soci-3 and therefore only indicators Soci-1.1 and Soci-2 were scale-dependent. Figure 5.3 indicates that the only input variable related to the scaling of the data with a notable impact on the social index value is the potential South African share of the global platinum jewellery market, but this impact is very small (amongst the smallest of all input values shown in Figure 5.3).

Considering sub-indicator Soci-1.1 (number of employees), the jewellery industry is superior to the catalytic converter industry by significant margin with 8425 potential employees compared to the 1461 for the catalytic converter industry. Note that the 1461 employees reported for the catalytic converter industry is less than a third of the actual number of about 5000 employees reported by some sources (Dewar, 2012; NACAAM, 2016). This is seen to be indicative of the labour intensive nature of the South African catalytic converter industry compared to global standards. This number (1461 employees) is still used in the comparison in this investigation as the author is of the opinion that labour intensity will have to be reduced for the South African catalytic converter industry to remain competitive in the global market. Total employment of 1461 employees is therefore seen to be more indicative of the actual sustainable employment potential of the industry than the current employment numbers. Further, it should be noted that the employment potential of the jewellery industry remains superior, even if the current employment numbers are used in the comparison.

On the contrary to employment potential, the catalytic converter industry is far superior to the jewellery industry in terms of indicator Soci-2 (Health and safety risk), with only 18 recordable incidents annually, compared to the 186 by the jewellery industry. Therefore, only very large changes in the relative scale of the industries will result in a reversal of the ranks of the industries with regard to these indicators. The arbitrary assumption that a jewellery industry consuming 5% of the total platinum consumption for jewellery purposes in 2014 can be established in South Africa therefore has little influence on the ranking of the industries in the social dimension.

As mentioned above, with reference to Figure 5.3, the input variables with the most significant impact on the social index value were all scale-independent. Similar to what was observed for the environmental index, the indicator for which data could not be found (Soci-3) had the most significant impact on the social index value as it had to be varied to account for any outcome. Further, sub-indicators Soci-1.2 (impact of employment), Soci-5.3 (negative impacts on society in the supply chain) and Soci-6.2 (sale of banned or disputed products) had a significant influence on the social index value due to the similar performance of the industries in these sub-indicators. Varying these sub-indicator scores one point up and one point down in the uncertainty analysis resulted in overlapping scores for the industries, thereby influencing which industry is superior and therefore the index value. Finally, variation in sub-indicators Soci-4.1 and -5.1 had a very small, almost negligible, impact on the social index value.

5.4.4 Implications of the results

The relative overall superiority of the catalytic converter industry compared to the jewellery industry supports the current development policy priorities in South Africa which focusses more strongly on the automotive industry than the jewellery industry (prominently through the Automotive Production and Development Programme or APDP). As previously mentioned, the development of a platinum jewellery industry in South Africa is not a policy priority at the moment, although the potential of developing it along with the gold and diamond jewellery industries is recognised in the Beneficiation Strategy published in 2011 (South African Department of Mineral Resources, 2011).

Further, although the results of the comparison indicate that the catalytic converter industry is superior to the jewellery industry based on data from 2014, the long term sustainability of the catalytic converter industry is debatable. As noted in Chapter 4, catalytic converters can be seen as an interim solution that will be useful only until a better solution to the emission problem is found. However, internal combustion engines will almost definitely remain an important part of the world until at least 2050, thereby providing some assurance as to the medium to long term sustainability of the catalytic converter industry (although the industry will likely shrink considerably). From an economic perspective, the results indicate that it remains sensible to invest in the further development of the industry at policy-level, considering the foothold the catalytic converter industry in South Africa already has in terms of market share, vertical integration and expertise. However, it will remain challenging to further develop and improve the environmental and social dimensions of the industry without compromising economic sustainability.

On the other hand, the long term sustainability of the platinum jewellery industry can also not be guaranteed due to its dependence on cultural trends and societal preferences. But, as noted in Chapter 4, the rarity, useful properties and appearance of platinum means the likelihood of it becoming obsolete in the global jewellery market is very slim. Development of a platinum jewellery industry, perhaps facilitated by the development of specialised factors and by leveraging the knowledge and infrastructure developed by related industries, may create substantial value over the long term. Furthermore, it is of paramount importance that the development of a platinum jewellery industry is managed to ensure that the industry is globally competitive and to avoid the mistakes made in the development of the catalytic converter industry and the steel industry in South Africa. Both these industries are struggling at the moment to be globally competitive as a result of (at least to some extent) over-dependence on external factors, such as government incentives and low electricity prices, as cornerstones to the competitiveness of the industry.

Finally, using sustainability indicators to compare industries, as done here, once again highlights the extent to which most industries, including those considered here, are unsustainable. This once again emphasises the need for policymakers to continuously endeavour to, on the one hand, improve the sustainability of existing industries and, on the other hand, steer the development of new industries along the path of increasing sustainability.

5.5 Analysis of the utility of the framework

This section will now cover the utility of the framework as experienced during the process of applying it to the case study industries and interpreting the results subsequently generated. The discussion will take the form of a basic S.W.O.T. analysis where the utility of the framework is discussed in terms of strengths, weaknesses, opportunities and threats.

5.5.1 Strengths

- The framework successfully facilitated the comparison of the two case study industries and produced results that were transparent, easily interpretable and useful.

- The process of collecting data for the case study industries was quick, although some difficulties arose when organisations did not report some of the required indicators. Overall, the data collection process was still much more rapid than that required by a more in-depth feasibility study.

- The scaling of the case study data was easy and quick, but this might become more complex if it is desirable to compare future performance. Comparing the future performance of industries would require forecasting of various indicator values and would require consideration of different growth and inflation rates.

- The hierarchical structure of the framework was central to the interpretation of the results and their implications. Specific aspects in which there were large differences between the industries and others where industries performed similarly could be identified and used to inform objective interpretation of the results.

- The uncertainty analysis contributed significantly to the value realised from the results by providing some insight into the influence of input uncertainty and the underlying tendencies in the values of some of the indicators. The uncertainty analysis also improves the credibility of the results. Uncertainty analysis is considered an indispensable part of the framework.

- As noted in the earlier discussion of the economic index results, the framework rewards a holistically strong performance, which is one of the essential requirements when considering sustainable development potential. The framework correctly produces results that reflect the fact that complete dominance in some aspects does not make an industry sustainable as a whole.

- The framework can be used to compare any mineral or metal beneficiation industries. The framework may be applicable to industries outside this realm as well, although minor alterations may be required.

5.5.2 Weaknesses

- The framework is by nature reductionist, attempting to simplify a complex system to a few individually measurable aspects. This directly implies a loss of some information about the system and immediately opens the results to potential oversights. It is therefore once again stressed that the user of the framework has to be knowledgeable about the industries being considered and has to apply his/her own discretion in the interpretation of the results.

- Risk and impact scores are widely used in the framework to quantify qualitative aspects. These scores will always be subjective to some extent. These scores do also not explicitly consider the size of the industry in its quantification, although the importance of the size of the industry is implied.

- Country- or region-specific effects may be embedded in the organisational data used to represent an industry and thereby make the results inaccurate for the target country. Some country- or region-specific effects in the target country itself may also be neglected in the framework and may have to be taken into account when the results are interpreted.

- The dependence of the framework on publicly available information limits its utility as only listed companies typically publish sustainability reports and the appropriate information is therefore sometimes not available for small and upcoming industries (the fuel cell industry, for example).

- As the framework is based on the GRI G4 Sustainability Reporting Guidelines, it inherits some of the weaknesses of the GRI guidelines. For example, the GRI guidelines are mainly used by large, public companies that seek to disclose their sustainability performance annually and are of little use to small, medium and micro-sized enterprises (SMMEs) that don't publish annual sustainability reports. As a result, the information reported according to the GRI guidelines are typically representative of large public companies and using this information to represent a potential industry (as is done in the present framework) is therefore only accurate if the industry consists mainly of large enterprises and not SMMEs.

- Inconsistency in the reporting of some indicators may introduce some difficulty in the collection of the data and some inaccuracy in the results. The GRI indicators are fairly well-defined however, so this is not considered a major problem. A more pronounced problem arises when some organisations do not report all the GRI indicators, although such problems can be avoided by making use of industry average values.

- The brief discussion of the long term sustainability of the case study industries in Section 5.4.4 highlight an important shortcoming of the framework. As the framework makes use of retrospective data to compare industries, the long term future prospects of the subject industries are neglected. The framework does not, at the moment, take the expected trends in sector development and growth into account explicitly (this is left to be taken into account by decision-makers alongside the results generated by the framework). It might be sensible to incorporate this into the framework in the future.

- As a result of the above-mentioned weaknesses, the results generated by the framework can, at maximum, be seen as only indicative and not as absolute. This framework cannot, nor does it aim to, replace a detailed feasibility study.

5.5.3 Opportunities

- The framework does not at the moment explicitly consider the size of an industry in impact scores. An opportunity therefore exists to improve the quantification by impact scores by explicitly taking the size of the industry into account in the quantification process.

- The standardised nature of the GRI indicators makes the collection of the data easy. It may become possible to automate the collection of data from the annual reports of organisations by making use of a computer. This will also allow the user to construct a database of different organisations from which data can instantly be used in the framework.

- As mentioned by one of the experts in the validation process, this framework may be useful in an environmental impact assessment (EIA) to evaluate different opportunities and motivate why a specific opportunity was chosen for development. This possibility can be explored further.

- This framework was developed to be as generic as possible while still maintaining accuracy for metal beneficiation industries, which was the primary target of the framework. The framework might, perhaps with a few minor adjustments, also be of use to compare other industries.

5.5.4 Threats

- The framework is based on the GRI sustainability reporting guidelines, making it vulnerable to becoming obsolete if these guidelines become obsolete or irrelevant to industry. The GRI guidelines are the most widely used and referenced sustainability reporting guidelines in the world at present and as such this threat is considered unlikely, but nonetheless still a possibility.

- As mentioned before, a significant threat associated with the use of this framework is that the results it generates may be used inappropriately or to motivate wrongful decisions if the results are not generated and interpreted by informed users.

- Although the framework is constructed to assess sustainability as holistically as possible, the division of sustainability into three separate dimensions may enforce the wrongful traditional, compartmentalised view of sustainability, which might cause the users of the framework to miss crucial interrelationships between the dimensions.

5.6 Chapter 5: Conclusion

This chapter presented details on the application of the framework to the case study industries and thereby completed the third and final phase of the framework development methodology introduced in Figure 3.2 in Chapter 3. It was found that the framework successfully facilitates the comparison of potential industries and several strengths, weaknesses, opportunities and threats identified in the application process, were highlighted. The next chapter presents the conclusions that can be drawn from this investigation, as well as some recommendations for future work.

Chapter 6

Conclusion and recommendations

This chapter presents a summary of the significant conclusions drawn throughout the investigation, as well as some recommendations for future investigation.

6.1 Conclusions

This section presents the conclusions drawn throughout this investigation according to the phases through which this project was completed. Figure 6.1 presents a summary of the research outcomes in terms of the research objectives defined in Chapter 1 of this document. The outcomes of the project are then discussed. First, the conclusions from the literature review are discussed, followed by a discussion of those drawn from the development of the framework. Finally, the conclusions drawn from the application of the framework to the case study industries are discussed.

6.1.1 Literature review

The literature review highlighted several important factors to consider in the development of a framework such as the one developed in this study. Firstly, the concept of sustainable development and the ever-increasing emphasis on sustainable development as a holistic concept was described. It became clear that it is essential to consider the potential gains and impacts across all the dimensions of sustainability in the process of selecting industries most suitable for development. Capturing a comprehensive picture of these potential impacts and gains across all the dimensions of sustainability, however, requires the use of a number of sustainability indicators, which is difficult to use in decision-making due to the inability of the user to simultaneously consider all the indicators and draw an objective and transparent conclusion. The need for aggregation of indicators into a smaller number of indices, which are easier to use in the decision-making process, was therefore identified as one of the important parts of constructing a useful framework. This led the investiga-

Overall Objective: Develop a framework facilitating the rapid, high level comparison of potential beneficiation development opportunities by policymakers.	**Overall Research Question:** Can a framework be developed to enhance the rapid, high level comparison of beneficiation development opportunities by policymakers?	**Research outcomes:** The employed research method successfully guided the development and testing of the framework. The framework was found to generate potentially useful outputs.
Sub-objective 1: Review relevant literature on sustainable development, sustainability reporting frameworks and composite indices.	**Research question 1:** 1.1. What is sustainable development and why use it as basis? 1.2. How can sustainability indicators be aggregated? 1.3. What existing sustainability indicator frameworks can be used to form the basis for the present framework?	**Research question 1 outcome:** • A sustainable development perspective should form the foundation of the framework. • Sustainability indicators can be aggregated and this is well-described in literature. • Many sustainability indicator frameworks exist. Based on several criteria, the GRI G4 guidelines were found most suitable to serve as a basis for the present framework.
Sub-objective 2: Develop and validate a framework that can be used to facilitate the comparison of beneficiation opportunities.	**Research question 2:** 2.1. What should the structure and content of the framework be? 2.2. What should be considered in the selection of indicators to be used in the present framework? 2.3. How should the framework use the input data to generate results?	**Research question 2 outcome:** • The developed framework consists of 18 equally-weighted indicators that are aggregated to produce a single index value for each dimension of sustainable development. • The indicators were selected based on defined requirements. • The developed framework was validated by consultation with relevant experts (who generally found the initial framework sensible) and some alterations were made to improve the initial framework based on their inputs.
Sub-objective 3: Illustrate the utility of the framework by comparison and analysis of potential metal beneficiation industries that can be established in South Africa.	**Research question 3:** 3.1. What industry can be used as a case study and what is its global structure? 3.2. How should data be collected and processed to be used in the framework? 3.3. What are the results of the comparison of potential development opportunities by using the framework?	**Research question 3 outcome:** • Based on an overview of the global platinum value chain, the catalytic converter industry and platinum jewellery industry were chosen as case study industries. • Data collection from annual reports of organisations was found easy and quick, although some data could not be found. • The results generated by the framework were found easily interpretable and useful, although input data that could not be found increased output uncertainty significantly. • Overall, the framework was found potentially useful, although some further adjustments can be made to improve its utility and accuracy.

Figure 6.1: Summary of the project outcomes in terms of the research objectives

tion into the theory of indicator aggregation methodologies and several viable alternatives were found to exist. Several existing sustainability assessment frameworks potentially suitable for forming the basis of the present framework were also identified and discussed.

6.1.2 Development of the framework

With the background provided by the literature review, the process of developing the framework followed. This process started with an elaboration on why an existing sustainability assessment framework should be used as basis for the present framework, followed by selection of the GRI G4 sustainability reporting guidelines to be used for this purpose. The conclusion that the GRI G4 guidelines were the most appropriate for the stated purpose was based on several criteria, most prominently its use of a comprehensive set of standardised indicators and its widespread use globally.

The development process then proceeded to the phase where the GRI indicators were sieved to retain only indicators suitable to be used in the framework, namely, those that were generalisable for an entire industry and were applicable to industries not yet established in a country. 32 indicators across all three dimensions of sustainability were left and the scope of these indicators as well as the grouping and judgement of the impact of each was defined.

The aggregation methodology for the remaining indicators could then be defined. Based on the discussion of the theory regarding indicator weightings in Chapter 2, it was concluded that equal weightings would be used for all indicators in the framework. This decision primarily stems from the recognition that no dimension of sustainability can be considered more important than another and therefore all the dimensions should be equally weighted. Further, the importance of each aspect considered within each dimension was also considered of equal importance. Non-compensatory multi-criteria (NCMC) aggregation was then identified as the most appropriate for the present framework. It was concluded that its non-compensatory nature was a requirement for the present framework as the good performance of an industry in some aspects cannot be allowed to offset its poor performance in others. This choice of aggregation method implied that no normalisation of data was required, which was seen as an advantage as this avoids the possibility of introducing more subjectivity into the results generated by the framework by a specific choice of normalisation method.

Finally, the developed framework was validated by consultation with relevant experts involved in the case study (platinum) industry or sustainability research. Feedback from the experts was generally positive. The feeling was that the framework was sufficiently comprehensive and potentially useful, although responses were mixed regarding the innovativeness of the framework. Some alterations were deemed necessary based on the responses. Firstly, indicators quantifying some aspects in terms of impact scores, including the life cycle impact of material and energy consumption, the quality of waste produced and the impact of employment in a specific industry, were added. Further, indicators Econ-5 and Econ-6 were added so as to explicitly quantify the competitiveness of an industry and the potential impact of socio-economic factors on an industry.

6.1.3 Application of the framework

Following the development and validation of the framework the case study industries to be used to test the utility of the framework could be selected and studied. Platinum was chosen as the subject metal due to its strategic importance in South Africa, the large number of well-established platinum-consuming industries that exist globally and the availability of accurate information on these industries. Some background to the production and consumption of platinum globally was then presented. South Africa traditionally dominates global platinum production, consistently producing more than 70 per cent of global production. In 2013, China dominated global platinum consumption (28 per cent of consumption), followed by Europe (21 per cent) and North America (13 per cent). The production of catalytic converters remained the largest platinum-consuming industry globally (37 per cent of consumption in 2013), followed by the production of platinum jewellery (33 per cent).

The catalytic converter industry and the platinum jewellery industry were chosen as case study industries to test the utility of the framework. The catalytic converter industry was chosen due to its importance in the global platinum value chain and as such an industry already exists in South Africa. The platinum jewellery industry was also selected for its global significance, but also for its potential significance to South Africa.

The utility of the framework could then be tested by application to these industries. It was found that the collection of data for the case study industries was easy and rapid but that in some cases data could not be found. This was as a result of some organisations not reporting all the required GRI indicators. The indicators for which data could not be found were accounted for in the uncertainty analysis. The scaling of the data from organisation-level to industry-level was found to be fairly simple as well, but that several assumptions and estimates had to be made in the scaling process.

The results generated by the framework were found to be clear, transparent and useful, but the importance of doing uncertainty analysis also became apparent. The influence of some assumptions, estimates and missing data was found to be significant and it was concluded that uncertainty analysis was an indispensable part of ensuring the results generated by the framework are accurate and meaningful. Further, it was found that the hierarchical structure of the framework enhanced the ability of the user to analyse the results and come to meaningful conclusions. It was also found that the framework correctly rewards a holistically strong performance by an industry and that the results are not skewed by extremely poor or extremely good performances in some dimensions. Some of the weaknesses of the framework identified by its application was its inherent reductionist nature and the potential for subjectivity in the input data used. Further, unavailability of input data, inconsistency in input data and embedded effects in input data were highlighted as potential weaknesses of the framework. Some opportunities and threats to the use of the framework were also pointed out.

The results generated by the framework indicated that the catalytic converter industry was superior to the platinum jewellery industry in the economic and social dimensions (92 per cent and 81 per cent confidence, respectively), but that the jewellery industry was superior in the environmental dimension (71 per cent confidence). Considering the uncertainty analysis results, it was concluded that there is a 90 per cent chance that the catalytic converter industry performs at least as well as the jewellery industry in the economic and social dimensions. The overlap of the 90 per cent confidence intervals of the industries in the environmental dimension indicates that the performance of both industries are very similar in this dimension and that neither is completely superior to the other.

The implications of these results were also discussed briefly. The superiority of the catalytic converter industry strongly supports the current policy in South Africa which focusses more on supporting further development of the catalytic converter industry than it does on the establishment of a new platinum jewellery industry. However, the long term sustainability of the catalytic converter industry was briefly challenged and discussed, after which the conclusion was reached that significant value may still be captured from the industry although it will most likely in the future become obsolete with the decreasing use of combustion engines. Similarly, the dependence of the platinum jewellery industry on cultural trends and societal preferences was highlighted as a potential threat to its long term sustainability, although it was concluded that the exclusive, good characteristics of platinum will likely continue to subdue this danger sufficiently.

6.2 Recommendations

Several recommendations can be made with regard to further refining the developed framework as well as its application. It can firstly be recommended that the framework results generated in this study be evaluated further, perhaps by a consultation process with knowledgeable people in the case study industries, in order to determine whether most of the important aspects were taken into account by the framework. This would once more ensure the framework is indeed comprehensive enough to generate accurate results. The framework can further also be applied to more case study industries in order to further validate the accuracy of the results it generates.

It can further be suggested that the possibility of broadening the framework to explicitly identify and include important local factors unique to the target country be investigated. As explained earlier in this document, the generic nature of the framework makes it applicable to any metal beneficiation industry, but has the drawback of possibly causing the framework to overlook some important local factors. An additional framework designed to identify the most important local factors regarding a specific industry or a consultation process with knowledgeable people involved in the relevant industries may be appropriate to ensure the results generated by the present framework include all relevant local and generic factors.

Furthermore, some improvements might be made in terms of the use of input data. Firstly, industry average values can be used for input values to the framework instead of using only data from a single organisation. This will ensure that the input data is representative of the industry and will avoid the problems with some organisations not reporting all the required GRI indicators. It might also be worth investigating a method of quantifying the appropriateness of the input data before it is used to generate results. This might entail, inter alia, setting clear criteria for the selection of organisations from which data is gathered and mapping out distortions and embedded effects in the data that result from region-, country- or organisation-specific events, or outlier events. Furthermore, it might be sensible include the size of an industry in the allocation of risk or impact scores. This would ensure that potentially larger industries are penalised more for impacts than smaller industries, as impacts of the same severity for a smaller industry will likely be less detrimental overall.

As mentioned in the S.W.O.T. analysis, it might be worthwhile to include consideration of the expected trends in sector development and growth in the comparison of industries, such that industries with clear future upside in terms of development potential is favoured in the results generated (the future growth of the catalytic converter industry, for example, may be expected to be considerably lower than that of the fuel cell industry). When incorporating this into the framework, it might be sensible to also consider the structure of the value chains of the subject industries explicitly, so as to aid in the quantification of the development potential of an industry. Some value chain structures may be more appropriate and favourable for development in some economies, based on existing industry structures or country-specific policy priorities. However, it should also be investigated whether it is sensible to attempt to quantify future development potential and how that could be done in the present framework.

It can further also be recommended that the indirect economic impacts of an industry be emphasised more in the framework. Indicator Econ-3, which quantifies indirect economic impacts in the framework at present, considers a vast array of impacts, ranging from the impact of the vertical, horizontal and lateral economic linkages generated by an industry to the impact of using the products and services of the industry. It also considers, amongst others, the impact of the industry on public infrastructure and the impact of the industry on the skills and knowledge amongst a community or in a geographical region. These impacts may all in their own right have far reaching consequences and it seems insufficient to collectively quantify these impacts in terms of only one indicator. It is therefore suggested that the weighting of this indicator be adjusted to make up a larger portion of the economic dimension (taking care to ensure all the dimensions remain equally weighted). It is further also suggested that the indicator be divided into several sub-indicators so as to facilitate better quantification of all the aspects it includes.

Finally, the framework can be applied to other metal beneficiation industries (including other platinum-consuming industries) that can potentially be developed in South Africa in order to identify the most viable opportunities and promote their development. Titanium, manganese, chromium, zirconium and gold are all, for example, produced in globally significant amounts in South Africa, but little is beneficiated locally. Application of the framework to identify industries that can be developed to capture more value from these resources may be of great value.

List of References

4th Energy Wave (2016). The Fuel Cell and Hydrogen Annual Review 2016. [Online]. Available at: http://www.4thenergywave.com. [2016, July 19].

Anglo American Platinum Ltd. (2014). Anglo American Platinum powers Kroonstad community by launching the world's first fuel cell mini-grid rural electrification field trail. Media release, 5 August 2014. [Online]. Available at: http://southafrica.angloamerican.com/media/press-releases/2014/05-08-2014.aspx. [2015, 20 April].

Anglo American Platinum Ltd. (2016). Inflection points for PGMs: Investing in Africa. Presentation at Barclays Mining Indaba 2016, 8-11 February 2016. Available at: http://www.angloamericanplatinum.com/investors/investor-presentations/2016.aspx. [2016, April 21].

Automotive Industry Export Council (2015). Automotive Export Manual 2015. [Online]. Available at: http://www.aiec.co.za/. [2016, April 21].

Azapagic, A. (2004). Developing a framework for sustainable development indicators for the mining and minerals industry. *Journal of Cleaner Production*, vol. 12, no. 6, pp. 639–662.

Azapagic, A. and Perdan, S. (2000). Indicators of sustainable development for industry: a general framework. *Trans IChemE*, vol. 78, no. July, pp. 243–261.

Baartjes, N. and Gounden, K. (2011). Synopsis of the first report of mineral resources and reserves in South Africa. Internal Report September, EcoPartners.

Baxter, R. (2014). Promoting Beneficiation in South Africa. Presentation to the Parliamentary Portfolio Committee on Trade and Industry, 10 September 2014. Available at: https://www.thedti.gov.za/parliament/2014/CoM.pdf. [2015, June 9].

Bessarabov, D., Van Niekerk, F., Van Der Merwe, F., Vosloo, M., North, B. and Mathe, M. (2012). Hydrogen Infrastructure within HySA national program in South Africa: Road map and specific needs. *Energy Procedia*, vol. 29, no. 18, pp. 42–52.

Brandi, H.S., Daroda, R.J. and Olinto, A.C. (2014). The use of the Canberra metrics to aggregate metrics to sustainability. *Clean Technologies and Environmental Policy*, vol. 16, no. 5, pp. 911–920.

Carter, C.R. and Rogers, D.S. (2008). A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management*, vol. 38, no. 5, pp. 360–387.

Cawthorn, R.G. (2010). The platinum group element deposits of the Bushveld Complex in South Africa. *Platinum Metals Review*, vol. 54, no. 4, pp. 205–215.

CDP (2016). [Online]. Available at: www.cdp.net. [2016, April 3].

Ciegis, R., Ramanauskiene, J. and Startiene, G. (2009). Theoretical reasoning of the use of indicators and indices for sustainable development assessment. *Engineering Economics*, vol. 3, no. 63, pp. 33–40.

Climate Disclosure Standards Board (2015). CDSB Framework for reporting environmental information & natural capital. [Online]. Available at: http://www.cdsb.net. [2016, April 3].

Cowley, A. and Woodward, B. (2011). A healthy future: Platinum in medical applications. *Platinum Metals Review*, vol. 55, no. 2, pp. 98–107.

Crundwell, F.K., Moats, M.S., Ramachandran, V., Robinson, T.G. and Davenport, W.G. (2011). Platinum-Group Metals, Production, Use and Extraction Costs. In: *Extractive Metallurgy of Nickel, Cobalt and Platinum Group Metals*, chap. 31, pp. 395 − 409. Elsevier Ltd.

Dewar, K. (2012). The Catalytic Converter Industry in South Africa. In: *Platinum 2012*, pp. 893–904. The Southern African Institute of Mining and Metallurgy.

Du Plessis, J.A. and Bam, W.G. (Forthcoming). Scoping phase comparison of development opportunities by making use of publicly available sustainability information. In: *Procedia Manufacturing: 14th Global Conference on Sustainable Manufacturing*.

Dworzanowski, M. (2013). The role of metallurgy in enhancing beneficiation in the South African mining industry. *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 113, no. 9, pp. 677–683.

Elkington, J. (1994). Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development. *California Management Review*, vol. 36, pp. 90–100.

Fassas, A.P. (2012). Exchange-Traded Products investing and Precious Metal prices. *Journal of Derivatives & Hedge Funds*, vol. 18, no. 2, pp. 127–140.

Fonseca, A., McAllister, M.L. and Fitzpatrick, P. (2013*a*). Measuring what? A comparative anatomy of five mining sustainability frameworks. *Minerals Engineering*, vol. 46-47, pp. 180–186.

Fonseca, A., McAllister, M.L. and Fitzpatrick, P. (2013*b*). Sustainability reporting among mining corporations: a constructive critique of the GRI approach. *Journal of Cleaner Production*, vol. 84, pp. 70–83.

Gary, J.H. and Handwerk, G.E. (2001). *Petroleum Refining: Technology and Economics*. Marcel Dekker Inc, New York. ISBN 0824704827.

Givan, D.A. (2007). Precious Metals in Dentistry. *Dental Clinics of North America*, vol. 51, no. 3, pp. 591–601. ISSN 00118532.

Global Reporting Initiative (2013*a*). G4 Sector Disclosures: Mining and Metals. [Online]. Available at: https://www.globalreporting.org/standards/Pages/default.aspx. [2015, September 22].

Global Reporting Initiative (2013*b*). G4 Sustainability Reporting Guidelines: Implementation Manual. [Online]. Available at: https://www.globalreporting.org/standards/Pages/default.aspx. [2015, September 22].

Global Reporting Initiative (2013*c*). G4 Sustainability Reporting Guidelines: Reporting principles and standard disclosures. [Online]. Available at: https://www.globalreporting.org/standards/Pages/default.aspx. [2015, August 17].

Global Reporting Initiative (2015). G4 Sustainability Reporting Guidelines Frequently Asked Questions. [Online]. Available at: https://www.globalreporting.org/standards/Pages/default.aspx. [2015, October 6].

Global Reporting Initiative and United Nations Global Compact (2013). Making the Connection: Using the GRI G4 Guidelines to Communicate Progress on the UN Global Compact Principles. [Online]. Available at: https://www.globalreporting.org/resourcelibrary/UNGC-G4-linkage-publication.pdf. [2016, April 3].

Global Reporting Initiative, United Nations Global Compact and WBCSD (2015). SDG Compass: The guide for business action on the SDGs. [Online]. Available at: http://sdgcompass.org/. [2015, October 7].

Hak, T., Moldan, B. and Dahl, A.L. (eds.) (2012). *Sustainability Indicators: A Scientific Assessment*. Island Press, Washington, D.C, USA. ISBN 9781597261319.

Heidenberger, K. and Stummer, C. (1999). Research and development project selection and resource allocation: A review of quantitative modelling approaches. *International Journal of Management Reviews*, vol. 1, no. 2, pp. 197–224. ISSN 1460-8545.

Heraeus Group (2016). [Online]. Available at: https://www.heraeus.com. [2016, July 19].

Hsu, T., Lucas, A., Qiu, Z., Li, M. and Yu, Q. (2014). Exploring the Chinese Gem and Jewelry Industry. *Gems & Gemology*, vol. 50, no. 1, pp. 2–29. ISSN 0016-626X.

IISD (2004). The Compendium of Sustainable Development Indicator Initiatives. [Online]. Available at: https://www.iisd.org/measure/compendium/. [2015, September 23].

IISD and OECD (2009). Bellagio STAMP: Sustainability Assessment and Measurement Principles. Tech. Rep..

Impala Platinum Ltd. (2015). Implats launches fuel cell as alternative energy supply. Media release, 1 April 2015. [Online]. Available at: http://www.implats.co.za. [2015, 21 July].

International Integrated Reporting Council (2013). The International <IR> Framework. [Online]. Available at: http://integratedreporting.org/resource/international-ir-framework/. [2016, April 5].

Johnson Matthey (2006). Platinum 2006 Special feature: Other Applications for Platinum. Platinum Group Metals Market Review. [Online]. Available at: http://www.platinum.matthey.com/services/market-research/market-review-archive/platinum-2006. [2015, June 27].

Johnson Matthey (2011). Platinum 2011 Special Feature: PGM in Glass Manufacturing. Platinum Group Metals Market Review. [Online]. Available at: http://www.platinum.matthey.com/services/market-research/market-review-archive/platinum-2011. [2015, June 26].

Johnson Matthey (2012). Platinum 2012 Special Feature: The Russian PGM Mining Industry. Platinum Group Metals Market Review. [Online]. Available at: http://www.platinum.matthey.com/services/market-research/market-review-archive/platinum-2012. [2016, July 15].

Johnson Matthey (2013). Platinum 2013. Platinum Group Metals Market Review. [Online]. Available at: http://www.platinum.matthey.com/services/market-research/market-review-archive/platinum-2013. [2015, June 8].

Johnson Matthey (2014). Market Data Tables: Platinum Supply and Demand. [Online]. Available at: http://www.platinum.matthey.com/services/market-research/market-data-tables. [2015, June 9].

Johnson Matthey (2015). PGM Market Report November 2015. [Online]. Available at: http://www.platinum.matthey.com/services/market-research/november_2015. [2016, August 5].

Johnson Matthey (2016). Johnson Matthey Precious Metals Management. [Online]. Available at: www.platinum.matthey.com. [2016, July 19].

Jones, H. and Botha, N. (2014). Accelerating the fuel cell Industry in South Africa. In: *The 6th International Platinum conference: 'Platinum - Metal for the Future'*, pp. 317–324. The Southern African Institute of Mining and Metallurgy.

Jones, R.T. (2005). An overview of Southern African PGM smelting. In: *Nickel and Cobalt 2005: Challenges in Extraction and Production, 44th Annual Conference of Metallurgists*, pp. 147–178. Canadian Institute of Mining.

Khan, M., Serafeim, G. and Yoon, A. (2015). Corporate Sustainability: First Evidence on Materiality. Working Paper 15-073, Harvard Business School.

KPMG (2013). The KPMG Survey of Corporate Responsibility Reporting 2013. [Online]. Available at: https://home.kpmg.com/xx/en/home/insights/2013/12/kpmg-survey-corporate-responsibility-reporting-2013.html. [2015, September 26].

Krajnc, D. and Glavič, P. (2005). A model for integrated assessment of sustainable development. *Resources, Conservation and Recycling*, vol. 43, no. 2, pp. 189–208. ISSN 09213449.

Lewis, L.N., Stein, J., Gao, Y., Colborn, R.E. and Hutchins, G. (1997). Platinum catalysts used in the silicones industry: Their synthesis and activity in hydrosilylation. *Platinum Metals Review*, vol. 41, no. 2, pp. 66–75. ISSN 00321400.

Lozano, R. (2008). Envisioning sustainability three-dimensionally. *Journal of Cleaner Production*, vol. 16, no. 17, pp. 1838–1846. ISSN 09596526.

Lozano, R. (2013). Sustainability inter-linkages in reporting vindicated: A study of European companies. *Journal of Cleaner Production*, vol. 51, pp. 57–65. ISSN 09596526.

Mackenzie, W. and Cusworth, N. (2007). The use and abuse of feasibility studies. In: *Project Evaluation Conference*, pp. 1–12. The Australasian Institute of Mining and Metallurgy. ISBN 9781920806668.

Marchi, S., Sangermano, M., Meier, P. and Kornmann, X. (2015). A Comparison of the Reactivity of Two Platinum Catalysts for Silicone Polymer Cross-Linking by UV-Activated Hydrosilation Reaction. *Macromolecular Reaction Engineering*, vol. 9, no. 4, pp. 360–365. ISSN 1862832X.

MMSD (2002). Seven Questions to Sustainability: How to Assess the Contribution of Mining and Minerals Activities. [Online]. Available at: http://www.iisd.org/library/seven-questions-sustainability-how-assess-contribution-mining-and-minerals-activities. [2015, October 7].

Mudd, G.M. (2012). Key trends in the resource sustainability of platinum group elements. *Ore Geology Reviews*, vol. 46, pp. 106–117. ISSN 01691368.

Munda, G. (2005). "Measuring Sustainability": A Multi-Criterion Framework. *Environment, Development and Sustainability*, vol. 7, no. 1, pp. 117–134. ISSN 15732975.

Munda, G. and Nardo, M. (2009). Noncompensatory/nonlinear composite indicators for ranking countries: a defensible setting. *Applied Economics*, vol. 41, no. 12, pp. 1513–1523. ISSN 00036846.

NACAAM (2016). NACAAM Profile. [Online]. Available at: http://naacamdirectory.webhouse.co.za/pages/32917. [2016, July 22].

Nakamura, D. and Kootungal, L. (2007). Clean fuels requirements increase catalyst demand. *Oil & Gas Journal*, vol. 105, no. 37, pp. 52–56. ISSN 13514180.

Nassar, N.T. (2015). Limitations to elemental substitution as exemplified by the platinum-group metals. *Green Chemistry*, vol. 17, pp. 2226–2235. ISSN 14639262.

Niemeijer, D. (2002). Developing indicators for environmental policy: data-driven and theory-driven approaches examined by example. *Environmental Science & Policy*, vol. 5, no. 2, pp. 91–103. ISSN 14629011.

Noort, D. and Adams, C. (2006). Effective Mining Project Management Systems. In: *International Mine Management Conference 2006*, pp. 87–96. The Australasian Institute of Mining and Metallurgy.

OECD and European Commission (2008). *Handbook on Constructing Composite Indicators: Methodoloy and User Guide*. OECD Publishing, Paris, France. ISBN 978-92-64-04345-9.

Parmon, V.N., Simagina, V.I. and Milova, L.P. (2010). Precious metals in catalyst production. *Catalysis in Industry*, vol. 2, no. 3, pp. 199–205. ISSN 2070-0504.

Parris, T.M. and Kates, R.W. (2003). Characterizing and Measuring Sustainable Development. *Annual Review of Environment and Resources*, vol. 28, no. 1, pp. 559–586. ISSN 1543-5938.

PESTLE Analysis (2016). What is PESTLE Analysis? A tool for Business Analysis. [Online]. Available at: http://pestleanalysis.com/what-is-pestle-analysis/. [2016, June 10].

Porter, M.E. (1980). Industry Structure and Competitive Strategy: Keys to Profitability. *Financial Analysts Journal*, vol. 36, no. 4, pp. 30–41.

Porter, M.E. (1990). The Competitive Advantage of Nations. *Harvard Business Review*, vol. 68, no. 2, pp. 73–93. ISSN 00178012.

Pulselli, F.M., Coscieme, L., Neri, L., Regoli, A., Sutton, P.C., Lemmi, A. and Bastianoni, S. (2015). The world economy in a cube: A more rational structural representation of sustainability. *Global Environmental Change*, vol. 35, pp. 41–51. ISSN 09593780.

Roberts, H.W., Berzins, D.W., Moore, B.K. and Charlton, D.G. (2009). Metal-ceramic alloys in dentistry: A review. *Journal of Prosthodontics*, vol. 18, no. 2, pp. 188–194. ISSN 1059941X.

Sadykov, V., Isupova, L., Zolotarskii, I., Bobrova, L., a.S Noskov, Parmon, V., Brushtein, E., Telyatnikova, T., Chernyshev, V. and Lunin, V. (2000). Oxide catalysts for ammonia oxidation in nitric acid production: properties and perspectives. *Applied Catalysis A: General*, vol. 204, no. 1, pp. 59–87. ISSN 0926860X.

Saurat, M. and Bringezu, S. (2008). Platinum group metal flows of Europe, part I: Global supply, use in industry, and shifting of environmental impacts. *Journal of Industrial Ecology*, vol. 12, no. 5-6, pp. 754–767. ISSN 10881980.

Sikdar, S.K. (2009). On aggregating multiple indicators into a single metric for sustainability. *Clean Technologies and Environmental Policy*, vol. 11, no. 2, pp. 157–161. ISSN 1618954X.

Sikdar, S.K., Sengupta, D. and Harten, P. (2012). More on aggregating multiple indicators into a single index for sustainability analyses. *Clean Technologies and Environmental Policy*, vol. 14, no. 5, pp. 765–773. ISSN 1618954X.

Singh, R.K., Murty, H.R., Gupta, S.K. and Dikshit, A.K. (2009). An overview of sustainability assessment methodologies. *Ecological Indicators*, vol. 9, no. 2, pp. 189–212. ISSN 1470160X.

Sopian, K. and Wan Daud, W.R. (2006). Challenges and future developments in proton exchange membrane fuel cells. *Renewable Energy*, vol. 31, no. 5, pp. 719–727. ISSN 09601481.

South African Chamber of Mines (2015). Facts & Figures 2013/2014. [Online]. Available at: http://www.chamberofmines.org.za/industry-news/publications/facts-and-figures. [2015, June 9].

South African Department of Mineral Resources (2011). A beneficiation strategy for the minerals industry of South Africa. [Online]. Available at: http://www.dmr.gov.za/publications/viewcategory/162-beneficiation-strategy-june-2011.html. [2015, June 9].

South African Reserve Bank (2014). Quarterly Bulletin June 2014. [Online]. Available at: http://www.resbank.co.za/Publications/QuarterlyBulletins/. [2015, June 10].

Spiegel, R.J. (2004). Platinum and fuel cells. *Transportation Research Part D: Transport and Environment*, vol. 9, no. 5, pp. 357–371. ISSN 13619209.

State of California Department of Toxic Substances Control (2002). Wastewater Produced in Jewelry Manufacturing. [Online]. Available at: https://www.dtsc.ca.gov. [2016, July 25].

Stillwater Mining Company (2014). Opportunity Brought to Light: 2014 Annual Report. [Online]. Available at: http://investorrelations.stillwatermining.com. [2016, July 19].

Stilwell, L.C. (2004). Platinum in the South African economy. In: *International Platinum Conference: 'Platinum Adding Value'*, pp. 1–8. The Southern African Institute of Mining and Metallurgy.

Stokes, J. (1987). Platinum in the glass industry. *Platinum Metals Review*, vol. 31, no. 2, pp. 54–62. ISSN 0032-1400.

Sustainability Accounting Standards Board (2016). Implementation Guide For Companies. [Online]. Available at: http://using.sasb.org/implementation-guide-for-companies/. [2016, April 10].

Umicore (2016). Umicore Precious Metals Refining. [Online]. Available at: http://www.preciousmetals.umicore.com/PMR/. [2016, July 19].

United Nations Global Compact (2012). Basic Guide: Communication on Progress. [Online]. Available at: https://www.unglobalcompact.org/library/305. [2016, April 5].

United Nations Global Compact (2016*a*). [Online]. Available at: www.unglobalcompact.org. [2016, April 5].

United Nations Global Compact (2016*b*). A Global Compact For Sustainable Development – Business and the Sustainable Development Goals: Acting Responsibly and Finding Opportunities. [Online]. Available at: https://www.unglobalcompact.org/library/2291. [2016, April 5].

United States Geological Survey (2014). Platinum-Group Elements in Southern Africa – Mineral Inventory and an Assessment of Undiscovered Mineral Resources. Scientific Investigations Report 2010-5090-Q, United States Geological Survey.

Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F. and Verbruggen, A. (2014). Sustainability Assessment and Indicators: Tools in a Decision-Making Strategy for Sustainable Development. *Sustainability*, vol. 6, no. 9, pp. 5512–5534. ISSN 2071-1050.

Watts, J.C., Clarke, B. and Atilan, O. (2010). Jewellery shocks from China and India. In: *The 4th International Platinum Conference, Platinum in transition 'Boom or Bust'*, pp. 379–382.

Wilburn, D.R. and Bleiwas, D.I. (2004). Platinum-Group Metals – World Supply and Demand. U.S. Geological Survey Open-File Report 2004-1224, United States Geological Survey.

World Commission on Environment and Development (1987). *Our Common Future*. Oxford University Press, Oxford.

Yang, C.J. (2009). An impending platinum crisis and its implications for the future of the automobile. *Energy Policy*, vol. 37, no. 5, pp. 1805–1808. ISSN 03014215.

Yuantao, B.N. and Zhengfen, Y. (1999). Platinum Loss from Alloy Catalyst Gauzes in Nitric Acid Plants. *Platinum Metals Review*, vol. 43, no. 2, pp. 62–69.

Zhou, L., Tokos, H., Krajnc, D. and Yang, Y. (2012). Sustainability performance evaluation in industry by composite sustainability index. *Clean Technologies and Environmental Policy*, vol. 14, no. 5, pp. 789–803. ISSN 1618954X.

Appendices

Appendix A

Detailed breakdown of indicators

This appendix presents detail on each of the indicators and the sub-indicators used in the framework, as discussed in Chapter 3 of this document. Section A.1 first presents a key to interpreting the scope statements, followed by Sections A.2, A.3 and A.4 that, respectively, present the scope statements for the economic, environmental and social indicators and sub-indicators used in the framework. Section A.5 concludes this appendix with some detail on the GRI G4 indicators not included in the present framework, along with a reason for the exclusion of each.

Note that the scope statements for all indicators that form part of the GRI sustainability reporting guidelines (those where GRI identification numbers are provided in the scope statement) used in the present framework were altered only slightly in order to make the scope of these indicators suitable for the present purpose. The Global Reporting Initiative (2013a,b,c) is acknowledged as the original author of these scope statements throughout this appendix.

A.1 Key for interpreting scope statements

This section presents the key to interpret the scope statements presented in subsequent sections. Each scope statement presents the identification number of the indicator or sub-indicator used in the present framework, as well as the sub-indicators of which the indicator is composed or, where applicable, the relevant GRI indicators from which the indicator or sub-indicator is derived. Further, the name of the indicator is presented, along with its unit of measure, the aspect it quantifies and the sustainable development goals (SDGs) it addresses. Table A.1 presents the key to the colours and fonts used in the scope statements.

Table A.1: Key for interpreting breakdown of indicators

Designation	**Meaning**
Italics in scope statement	These parts can be excluded from the scope if a high level assessment is done
G4-XXX^{M}	Mining and metals sector disclosures were taken into account for this indicator
Econ-x	Refers to a specific economic indicator
Envi-x	Refers to a specific environmental indicator
Soci-x	Refers to a specific social indicator

A.2 Economic Indicators

This section first presents the scope statements for all the economic indicators, followed by the scope statements for all the economic sub-indicators in Section A.2.1.

Indicator ID	*Composed of*	*Indicator Name*	
Econ-1	**G4-EC1**^{M}	**Economic value**	
		Measured by:	Expected earnings (Monetary Units)
		Measured aspect:	Economic performance
		Relevant SDGs:	2,5,7,8,9

Scope:

The earnings reasonably expected for the industry, calculated by subtracting the expected operating costs, wages and taxation from the expected sales revenue. Note that some organisation-specific earnings and costs are not included in the calculation. Include:

- Direct economic values generated
  - Revenues
    - Net Sales
- Economic value distributed
  - Operating costs
    - Cash payments made outside the organization for materials, product components, facilities, and services purchased. Includes license fees, royalties, employee protective clothing, *property rental, facilitation payments, payments for contract workers and employee training costs (where outside trainers are used).*
  - Employee wages and benefits
    - Total payroll comprises employee salaries, including amounts paid to government institutions (such as employee taxes, levies, and unemployment funds) on behalf of employees.
    - *Total benefits include regular contributions (only pensions and insurance to be considered here).*
  - Payments to government
    - All organization taxes (such as corporate, income and property)

Adapted from Global Reporting Initiative (2013a,b,c).

Indicator ID	*Composed of*	*Indicator Name*	
Econ-2	**G4-EC2**	**Climate change risks**	
		Measured by:	Risk score
		Measured aspect:	Economic performance
		Relevant SDGs:	13

Scope:

Risks and opportunities posed by climate change that have the potential to generate substantive changes in operations, revenue or expenditure for the organization. The nature of the risk is to be quantified with the use of an impact-likelihood matrix. For the identified risks and opportunities, disclose the following characteristics and refer to these characteristics to quantify the risk using the matrix:

- The risk or opportunity driver - categorize the risk or opportunity:
  - Physical
  - Regulatory
  - Other
- Driver of the risk or opportunity driver - identify a particular piece of legislation, or a physical driver such as water scarcity
- The potential impact - describe potential impacts generally, including, as a minimum
  - Increased or reduced capital or operational costs
  - Increased or decreased demand for products and services
  - Increase or decrease in capital availability and investment opportunities
- The projected time frame in which the risk or opportunity is expected to have substantive financial implications
- Direct and indirect impacts - whether the impact will directly affect the organization, or indirectly affect the organization via the value chain
- Likelihood - the probability of the impact on the organization
- Magnitude of impact - the extent to which the impact, if occurring, would affect the organization financially

- The financial implications of the risk or opportunity before action is taken
- The methods used to manage the risk or opportunity (such as carbon capture and storage; fuel switching; use of renewable and lower carbon footprint energy; improving energy efficiency; flaring, venting and fugitive emission reduction; renewable energy certificates; and use of carbon offsets)
- The costs associated with these actions

Adapted from Global Reporting Initiative (2013a,b,c).

Indicator ID	*Composed of*	*Indicator Name*	
Econ-3	**G4-EC7** **G4-EC8**	**Indirect economic impacts**	
		Measured by:	Impact score
		Measured aspect:	Indirect economic impacts
		Relevant SDGs:	1,2,3,8,10,17

Scope:

Identify expected significant indirect economic impacts, both positive and negative, and express the sum of the impacts as an impact score. Impacts to consider may include:

- Changing the productivity of organizations, sectors, or the whole economy (such as through greater adoption or distribution of information technology)
- Stimulating the development of upstream-, downstream- and/or sidestream industries (as a result of the level of technology used by an industry, level of innovation and investment in research and development)
- Economic development in areas of high poverty (such as total number of dependants supported through income from one job)
- Economic impact of improving or deteriorating social or environmental conditions (such as changing job market in an area converted from small family farms to large plantations or the economic impacts of pollution)

- Availability of products and services for those on low incomes (such as preferential pricing of pharmaceuticals contributes to a healthier population that can participate more fully in the economy; pricing structures that exceed the economic capacity of those on low incomes)
- Enhancing skills and knowledge amongst a professional community or in a geographical region (such as need for a supplier base creates a magnet for organizations with skilled workers, which in turn engenders new learning institutes)
- Jobs supported in the supply chain or distribution chain (such as assessing the impacts of growth or contraction of the organization on its suppliers)
- Stimulating, enabling, or limiting foreign direct investment (such as expansion or closure of an infrastructure service in a developing country can lead to increased or reduced foreign direct investment)
- Economic impact of development of new infrastructure or deterioration of infrastructure due to intensive use as a result of the new industry
- Economic impact of change in location of operations or activities (such as outsourcing of jobs to an overseas location)
- Economic impact of the use of products and services (such as linkage between economic growth patterns and use of particular products and services)

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Composed of*	*Indicator Name*	
Econ-4	**G4-EC9**^{M}	**Local suppliers**	
		Measured by:	Percentage of operating cost
		Measured aspect:	Procurement practices
		Relevant SDGs:	12

Scope:

Report the percentage of the procurement budget expected to be spent on local suppliers (such as percentage of products and services purchased locally).

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Composed of*	*Indicator Name*	
Econ-5	**Econ-5.1** **Econ-5.2** **Econ-5.3** **Econ-5.4**	**Competitiveness**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

This indicator quantitatively captures four strategic factors that may influence the potential success of an industry in a given competitive socio-economic environment. These factors are based on Porter's Diamond of National Advantage and include factor conditions, demand conditions, related & supporting industries and rivalry (Porter, 1990). These factors are quantified in the form of impact scores captured by sub-indicators Econ-5.1 through Econ-5.4.

Indicator ID	*Composed of*	*Indicator Name*	
Econ-6	**Econ-6.1** **Econ-6.2** **Econ-6.3**	**Socio-economic factors**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

Some socio-economic factors in a country, including political, regulatory and cultural considerations, may have an influence on the suitability of establishing some industries in that country. This indicator reflects the potential impact of these factors on an industry in the form of an impact score, composed from three sub-indicators. Sub-indicators Econ-6.1 through Econ-6.3 captures, respectively, the potential impact of political-, regulatory- and cultural factors on the feasibility of an industry.

A.2.1 Economic sub-indicators

This section presents the scope statements for the sub-indicators of which the indicators in Section A.2, above, are composed.

Indicator ID	*Derived from*	*Indicator Name*	
Econ-5.1	**Porter (1990)**	**Factor conditions**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

This indicator quantitatively captures the potential impact of some factor conditions (as described by Porter (1990)) on the feasibility of an industry in a country. Report the perceived impact score, considering the following factors:

- **Basic factors** (such as a pool of labour or a local raw material source) that may contribute to competitiveness (according to classical economic theory) but do not require substantial and sustained investment to be developed and can be easily acquired through global networks or circumvented through technology, for example. These factors have less significant impacts on competitiveness than specialized factors that cannot easily be imitated by competitors.
- **Specialized factors** contributing to competitiveness, developed by substantial and sustained investment (in world class research institutions, for example) that cannot easily be imitated by international competition through global trade networks or technology. The impacts of these factors on the competitiveness of an industry are more significant than that of basic factors.

Adapted from Porter (1990).

Indicator ID	*Derived from*	*Indicator Name*	
Econ-5.2	**Porter (1990)**	**Demand conditions**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

This indicator quantitatively captures the potential impact of some local demand conditions (as described by Porter (1990)) on the feasibility of an industry in a country. Report the perceived impact score, taking the following into consideration:

- The **character of local demand** has a major influence on the development of competitive local industries. An industry is more likely to be internationally competitive if the local demand for its product is sophisticated and sets stringent requirements. This forces the industry to be innovative and anticipate global trends.

- The **size of local demand** has a less significant influence on the global competitiveness of an industry than the character of the demand, but may nonetheless still have an impact. If an industry's importance and size is more significant in the national economy than globally, such an industry is likely to attract more investment, often making the industry more competitive globally.

Adapted from Porter (1990).

Indicator ID	*Derived from*	*Indicator Name*	
Econ-5.3	**Porter (1990)**	**Related & supporting industries**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

This indicator quantitatively captures the potential impact of local supporting and related industries (as described by Porter (1990)) on the feasibility of an industry in a country. Report the perceived impact score, taking the following into consideration:

- The presence of internationally competitive **supporting industries** (upstream or downstream of the industry being considered) may provide an industry with cost-effective inputs and expertise. Supplying or consuming industries located near the industry under consideration allows quick, easy and constant flow of information and may as such improve the rate of innovation and upgrading, thereby enhancing competitiveness.

- **Related industries** (producing similar products or targeting similar markets to the industry under consideration) provides similar benefits to supporting industries in that information flow and technical knowledge interchange is more rapid. Related industries also enlarge the pool of personnel possessing relevant skills from which an industry can recruit, thereby potentially having a positive influence on the competitiveness of the industry.

Adapted from Porter (1990).

Indicator ID	*Derived from*	*Indicator Name*	
Econ-5.4	**Porter (1990)**	**Rivalry**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

This indicator quantitatively captures the potential impact of local rivalry within an industry (as first described by Porter (1980) and Porter (1990)) on the success of the industry in a country. Report the perceived impact score, taking the following into consideration:

- Competition can discourage the establishment of a **new industry** or result in an industry that is overly dependant on goverment support. Competition can be evaluated in terms of the ease of entry of competitors into markets targeted by an industry, the bargaining power of suppliers and customers and the threat of substitutes to the products produced by the industry. Easy market entry by competitors, potential substitution by different products and suppliers and customers with large bargaining power (perhaps due to a monopolistic market position) decreases the feasibility of a new industry.
- Regarding already **established industries**, competition can be a strong stimulus that encourages dynamic improvement of an industry in order to remain competitive and may therefore have a positive impact on an industry.

Adapted from Porter (1990).

Indicator ID	*Derived from*	*Indicator Name*	
Econ-6.1	**PESTLE analysis**	**Political factors**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

The political past, present and potential future in a country may have a significant influence on the suitability of establishing some industries in that country. The level of government influence in the economy, the policies of the government and the prevalent national governance approach may favour some industries relative to others, thereby impacting the potential success of new industries.

Governmental incentive schemes may, for example, have a significant influence on the suitability of establishing some industries in that country. Some industries may be prioritised in terms of national or regional economic growth goals and may as such be heavily incentivised, making establishment of such an industry easier and more profitable than an industry that is not incentivised. This indicator captures these potential political impacts in the form of an impact score.

Adapted from PESTLE Analysis (2016).

Indicator ID	*Derived from*	*Indicator Name*	
Econ-6.2	**PESTLE analysis**	**Regulatory factors**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

The regulatory policy in terms of consumer-, safety- and labour laws and its enforcement, as well as applicable trade regulations and penalties may have a significant influence on the suitability of establishing some industries in that country. This indicator reflects the potential impact of these regulatory factors on an industry in the form of an impact score.

Adapted from PESTLE Analysis (2016).

Indicator ID	*Derived from*	*Indicator Name*	
Econ-6.3	**PESTLE analysis**	**Cultural & demographic factors**	
		Measured by:	Impact score
		Measured aspect:	Strategic considerations
		Relevant SDGs:	8,9

Scope:

The cultural past, prevailing cultural convictions, cultural diversity and the demography of a country may have an influence on the suitability of establishing some industries in that country. As such, some industries may be inherently at an advantage or disadvantage relative to others due to, for example, cultural stigmas related to prevailing or historic international industry practices. This indicator reflects the potential impact of such cultural factors on an industry in the form of an impact score.

Adapted from PESTLE Analysis (2016).

A.3 Environmental Indicators

This section first presents the scope statements for all the environmental indicators, followed by the scope statements for all the environmental sub-indicators in Section A.3.1.

Indicator ID	*Composed of*	*Indicator Name*	
Envi-1	**Envi-1.1** **Envi-1.2** **Envi-1.3**	**Material consumption**	
		Measured by:	Mass of material & impact of consumption
		Measured aspect:	Materials
		Relevant SDGs:	6,8,12
Scope: This indicator is composed of the approximate mass of material and water expected to be consumed annually by the industry, as well as the life cycle impact of the material that is consumed.			

Indicator ID	*Composed of*	*Indicator Name*	
Envi-2	**Envi-2.1** **Envi-2.2**	**Total energy consumption**	
		Measured by:	Joules (or multiples) of energy & impact of consumption
		Measured aspect:	Energy
		Relevant SDGs:	7,8,12,13
Scope: This indicator measures the direct and indirect energy expected to be consumed by the industry, as well as the life cycle impact of the energy consumption.			

Indicator ID	*Composed of*	*Indicator Name*	
Envi-3	**Envi-3.1** **Envi-3.2** **Envi-3.3** **Envi-3.4**	**Total gaseous emissions**	
		Measured by:	Mass of gaseous emissions
		Measured aspect:	Emissions
		Relevant SDGs:	3,12,13,14,15

Scope:

This indicator captures the mass of GHGs emitted directly and indirectly by the industry (as mass of CO_2 equivalent), the mass of ozone-depleting substances emitted (as mass of CFC-11 equivalent) and the mass of other noxious gasses emitted.

Indicator ID	*Composed of*	*Indicator Name*	
Envi-4	**Envi-4.1** **Envi-4.2** **Envi-4.3**	**Total waste discharge (including water, hazardous waste and normal process waste)**	
		Measured by:	Mass of waste discharge & overall quality of waste
		Measured aspect:	Effluents and waste
		Relevant SDGs:	3,6,12,14

Scope:

This indicator captures the mass of water discharged, the mass of hazardous waste discharged and the mass of overburden, rock, tailings and sludges discharged, as well as the overall quality of waste expected to be discharged.

Indicator ID	*Composed of*	*Indicator Name*	
Envi-5	**G4-EN28**	**Products and packaging materials reclaimed**	
		Measured by:	Percentage reclaimed
		Measured aspect:	Products and services
		Relevant SDGs:	8,12

Scope:

Calculate or estimate the percentage of products and their packaging materials reclaimed (that is, recycled or reused) at the end of their useful life. Do not count rejects and recalls of products.

Note that for a detailed assessment, separate indicators can be used to report the percentage recycled and reused, thereby allowing different weights to be allocated to the separate indicators (this is only sensible if one of the methods is deemed more desirable than the other and this has to be captured in the framework).

Calculate the percentage reclamation as the amount of products and packaging expected to be reclaimed during a period of time, divided by the total amount of products and packaging expected to be sold during the same period.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Composed of*	*Indicator Name*	
Envi-6	**G4-EN33**	**Supply chain environmental impacts**	
		Measured by:	Risk score
		Measured aspect:	Supplier environmental
		Relevant SDGs:	None

Scope:

Due to the prospective nature of this framework, it is not possible to assess the exact impacts that will occur in the supply chain. Further, the impacts of individual operations may differ. However, it is expected that the supply chain impacts for a supply chain in which similar materials are used to produce similar products can be approximated and generalised to a reasonable extent. This indicator therefore aims to capture the expected impacts of a typical supply chain and consumers for the specific industry being considered. The expected risk of negative environmental impacts in the supply chain can be assessed with the use of a impact-likelihood matrix. Negative impacts include those that are either caused or contributed to by the industry, or that are linked to its activities, products, or services by relationships with suppliers. Amongst other possible impacts, the loss of environmental resources as a result of the activities of the industry, its supply chain and its consumers should be considered. Note that the impact of material consumption and emissions are already captured in indicators EN3, EN4, and EN15 and EN17, respectively, and should therefore not be taken into account here.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

A.3.1 Environmental sub-indicators

This section presents the scope statements for the sub-indicators of which the indicators in Section A.3, above, are composed.

Indicator ID	*Derived from*	*Indicator Name*
Envi-1.1	**G4-EN1**	**Materials by weight**
		Measured by: Mass of material
		Measured aspect: Materials
		Relevant SDGs: 8,12

Scope:

Identify the organization's primary products and services. Identify the mass of total materials used. The material usage should, as a minimum, include:

- Raw materials (that is, natural resources used for conversion to products or services such as ores, minerals, wood)
- Associated process materials (that is, materials that are needed for the manufacturing process but are not part of the final product, such as lubricants for manufacturing machinery)
- Semi-manufactured goods or parts, including all forms of materials and components other than raw materials that are part of the final product
- Materials for packaging purposes, which include paper, cardboard and plastics

For detailed assessment, material derived from renewable and non-renewable sources can be reported as two separate indicators, thereby allowing different weights to be allocated to the indicators (if, for example, material use from renewables is deemed more desirable than use of non-renewable materials).

Adapted from Global Reporting Initiative (2013a,b,c).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-1.2	**G4-EN8**	**Water withdrawals by weight**	
		Measured by:	Mass of water
		Measured aspect:	Materials
		Relevant SDGs:	6
Scope: Identify the total mass of water withdrawn from any water source. This includes the abstraction of cooling water. Identify whether these calculations are estimated or modelled and the methods used. This Indicator may include water that was either withdrawn directly by the organization or through intermediaries such as water utilities.			

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-1.3		**Life cycle impact of material consumption**	
		Measured by:	Impact score
		Measured aspect:	Materials
		Relevant SDGs:	6
Scope: This indicator captures the life cycle impact of the material consumed by the industry in terms of an impact score. The environmental impact of an industry in terms of its material consumption is higher if it makes use of a wider range of input materials and complex input materials that require more raw materials and are more complex to produce. The impacts of using non-renewable materials are also generally higher than the impacts of using renewable materials. *If indicator G4-EN1 is split into two differently weighted indicators to report renewable and non-renewable material use in a detailed assessment, the impact of renewable material use compared to non-renewable material use should not be considered in the present indicator as to avoid double counting of the impact of using renewable or non-renewable materials.*			

Indicator ID	*Derived from*	*Indicator Name*	
Envi-2.1	**G4-EN3**	**Energy consumption (Scope 1 & 2)**	
		Measured by:	Joules (or multiples) of energy
		Measured aspect:	Energy
		Relevant SDGs:	7,8,12,13

Scope:

Identify the amount of energy (fuel, electricity, heating, cooling, and steam) expected to be consumed within the industry for the period investigated and calculate the total expected energy consumption in joules or multiples. Energy may be purchased from sources external to the industry or produced within the industry itself (self- generated).
For detailed assessment, energy derived from renewable and non-renewable sources can be reported as two separate indicators, thereby allowing different weights to be allocated to the indicators (to, for example, reward energy generation from renewables and penalise energy generation from non-renewables in the framework).

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-2.2	**G4-EN4**	**Life cycle impact of energy consumption**	
		Measured by:	Impact score
		Measured aspect:	Energy
		Relevant SDGs:	7,8,12,13

Scope:

Quantify the overall impact of energy consumed by the industry, as well as upstream and downstream activities associated with its operations in terms of an impact score. For this indicator, exclude magnitude of energy consumption as reported in indicator G4-EN3, but take into account the nature of this energy consumption – extensive use of renewable energy can, for example, be rewarded in terms of the impact score allocated in this indicator.
When determining the relevance of activities outside the industry, identify whether the activity's energy consumption:

- Contributes significantly to the total anticipated energy consumption outside of the industry

- Contributes to the industry's risk exposure to climate change-related risks such as financial, regulatory, supply chain, product and customer, litigation, and reputational risks
- Is deemed material by key stakeholders (such as customers, suppliers, investors, or civil society)
- Has been identified as significant in sector-specific guidance
- Meets any additional criteria for determining relevance, developed by the industry or by organizations in the industry

Identify relevant upstream or downstream energy consumption in the following categories and activities:
Upstream

1. Purchased goods and services
2. Capital goods
3. Fuel- and energy- related activities (those that are not included in Indicator G4-EN3)
4. Upstream transportation and distribution
5. Waste generated in operations
7. Employee commuting

   Other upstream

Downstream

9. Downstream transportation and distribution
10. Processing of sold products
11. Use of sold products
12. End of life treatment of sold products

    Other downstream

(Note the numbering is kept consistent with that in the G4 framework for easy reference)

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-3.1	**G4-EN15** **G4-EN17**	**GHG emissions (Scope 1 & 2)**	
		Measured by:	Mass of CO_2 equivalent
		Measured aspect:	Emissions
		Relevant SDGs:	3,12,13,14,15

Scope:

This Indicator covers the direct (Scope 1) and indirect (Scope 2) GHG emissions, in CO_2 equivalents. This indicator includes both the direct (Scope 1) and indirect (Scope 2) GHG emissions as the proportions of direct and indirect emissions will likely differ for organisations within an industry, but the total direct and indirect GHG emissions will likely be similar. It is therefore not sensible to attempt to capture the direct and indirect GHG emissions in separate indicators. The GHGs included in this indicator are those covered by the UN 'Kyoto Protocol' and the WRI and WBCSD 'GHG Protocol Corporate Accounting and Reporting Standard', namely:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)
- Nitrogen trifluoride (NF_3)

Calculate the gross direct (Scope 1) and indirect (Scope 2) GHG emissions using relevant GWP rates, as mass of CO_2 equivalent. Exclude any GHG trades, such as purchases, sales, or transfers of offsets or allowances. Identify direct emissions of GHGs from sources owned or controlled by the organizations in the industry under consideration, including:

- Generation of electricity, heating, cooling and steam. These emissions result from combustion of fuels in stationary sources (such as boilers, furnaces, turbines) and from other combustion processes such as flaring

- Physical or chemical processing. Most of these emissions result from the manufacturing or processing of chemicals and materials (such as cement, steel, aluminum, ammonia, and waste processing)

- *Transportation of materials, products, waste, employees, and passengers. These emissions result from the combustion of fuels in mobile combustion sources owned or controlled by an organization (such as trucks, trains, ships, airplanes, buses, cars)*

Identify indirect emissions of GHGs that result from the generation of the electricity, heating, cooling, and steam which is purchased or acquired for own consumption by the organizations in the industry under consideration. Exclude other indirect (Scope 3) emissions. These other indirect (Scope 3) emissions are reported in Indicator G4-EN17.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-3.2	**G4-EN17**	**GHG emissions (Scope 3)**	
		Measured by:	Mass of CO_2 equivalent
		Measured aspect:	Emissions
		Relevant SDGs:	3,12,13,14,15

Scope:

This Indicator covers the indirect (Scope 3) GHG emissions, in CO_2 equivalents. The GHGs included in this indicator are the same as those covered by G4-EN15, above. Calculate the indirect emissions that occur outside the industry (that are not reported under Indicator G4-EN16) using relevant GWP rates, as mass of CO_2 equivalent. This includes both upstream and downstream emissions. Indirect emissions may also come from the industry's waste decomposing processes and process-related emissions during the manufacturing of purchased goods. Exclude any GHG trades, such as purchases, sales, or transfers of offsets or allowances. When deciding the relevance of activities with regards to this indicator, consider whether the activity's emissions:

- Contribute significantly to the industry's total anticipated Scope 3 emissions

- Contributes to the industry's risk exposure to climate change-related risks such as financial, regulatory, supply chain, product and customer, litigation, and reputational risks
- Are deemed material by key stakeholders (such as customers, suppliers, investors, or civil society)
- Has been identified as significant in sector-specific guidance
- Meets any additional criteria for determining relevance, developed by the industry or by organizations in the industry

Identify relevant upstream or downstream emissions in the following categories and activities:
Upstream

1. Purchased goods and services
2. Capital goods
3. Fuel- and energy- related activities (those that are not included in Indicator G4-EN3)
4. Upstream transportation and distribution
5. Waste generated in operations
7. Employee commuting

   Other upstream

Downstream

9. Downstream transportation and distribution
10. Processing of sold products
11. Use of sold products
12. End of life treatment of sold products

    Other downstream

(Note the numbering is kept consistent with that in the G4 framework)

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-3.3	**G4-EN20**	**Ozone-depleting substances (ODS)**	
		Measured by:	Mass of CFC-11 equivalent
		Measured aspect:	Emissions
		Relevant SDGs:	3,12

Scope:

This Indicator covers the production, import, and export of substances covered in Annexes A, B, C, and E of the UNEP 'Montreal Protocol on Substances that Deplete the Ozone Layer' as well as any other ODS produced, imported, or exported by the industry. Identify ODS expected to be produced, imported, or exported by the industry. Calculate the approximate production of ODS as the expected amount of ODS produced, minus the expected amount destroyed by approved technologies and minus the expected amount entirely used as feedstock in the manufacture of other chemicals. Exclude ODS recycled and reused.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-3.4	**G4-EN21**^{M}	**NO_x, SO_x and other emissions**	
		Measured by:	Mass of noxious gas emissions
		Measured aspect:	Emissions
		Relevant SDGs:	3,12,14,15

Scope:

This indicator captures the amount of significant air emissions, in metric tons, for each of the following:

- NO_x
- SO_x
- Persistent organic pollutants (POP)
- Volatile organic compounds (VOC)
- Hazardous air pollutants (HAP)
- Particulate matter (PM)

- Other standard categories of air emissions identified in relevant regulations

Include emissions from both major mobile sources and on-site stationary sources.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-4.1	**G4-EN22**	**Water discharge**	
		Measured by:	Mass of water discharge
		Measured aspect:	Effluents and waste
		Relevant SDGs:	3,6,12,14

Scope:

This indicator captures the total mass of expected (planned) water discharges by the industry (excluding collected rainwater and domestic sewage). If the water discharges cannot be approximated by scaling from meter measurements, this figure needs to be estimated by subtracting the approximate mass consumed on-site in the industry from the mass withdrawn as reported in G4-EN8.

For detailed assessment, the expected water discharge can be reported as two (or more) separate indicators based on the expected quality of the water discharged, thereby allowing different weights to be allocated to the indicators (if, for example, water discharge of relatively good quality is deemed more desirable than discharge of highly contaminated water and quantification of the quality of discharge by indicator Envi-4.3 is deemed inadequate). In the case that more than one indicator is used to report water discharges of different qualities, indicator Envi-4.3 should not include the quality of water discharges in its quantification of overall waste quality in order to avoid double counting of the impact of water discharge quality.

Note that industries that discharge effluents or process water report water quality in terms of total volumes of effluent using standard effluent parameters such as Biological Oxygen Demand (BOD) or Total Suspended Solids (TSS). The specific choice of quality parameters will vary depending on the industry's products, services, and operations. The selection of parameters is to be consistent with those used in the industry. Water quality metrics may vary depending on national or regional regulations.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-4.2	**G4-EN23**^{M}	**Waste by type**	
		Measured by:	Mass of waste generated
		Measured aspect:	Effluents and waste
		Relevant SDGs:	3,6,12

Scope:

This indicator captures the total weight of hazardous and non-hazardous waste generated by the operations of the industry, categorized as:

- Hazardous waste (as defined by national legislation at the point of generation)
- Non-hazardous waste (all other forms of solid or liquid waste, excluding wastewater)

If no weight data are available, estimate the mass by scaling of available information on waste density and volume collected, mass balances, or similar information. Indicator G4-EN23 refers to site waste that can be expected to be generated in similar quantities by all organisations in the industry, e.g. waste oils and spent cell lining. Note that large-volume mining and mineral processing waste would be reported under MM3 and is not considered here. *For detailed assessment, waste of hazardous and non-hazardous nature, or waste of different qualities, can be reported as separate indicators, thereby allowing different weights to be allocated to the indicators (if, for example, non-hazardous waste is deemed more desirable than hazardous waste and quantification of the quality of the waste discharge by indicator Envi-4.3 is deemed inadequate). In the case that more than one indicator is used to report waste discharges of different qualities, indicator Envi-4.3 should not include the quality of waste discharges in its quantification of overall waste quality in order to avoid double counting of the impact of waste discharge quality.*
Separate indicators can also be used to report the total weight of hazardous and non-hazardous waste, according to different disposal methods. Disposal methods to be considered may include:

- *Reuse*
- *Recycling*
- *Composting*
- *Recovery, including energy recovery*

- Incineration (mass burn)
- Deep well injection
- Landfill
- On-site storage
- Other (to be specified by the organization)

Reporting separate indicators according to disposal method (or a group of disposal methods) will allow different weights to be allocated to the indicators, thereby allowing promotion of desirable methods and penalisation of less desirable methods. Further, for detailed assessment, other site waste such as office, canteen and camp waste, scrap steel, tires and construction waste may also be included. Note that these can only be included if the amounts of these wastes can be generalised accurately for the entire industry being considered.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Envi-4.3		**Overall quality of waste**	
		Measured by:	Impact score
		Measured aspect:	Effluents and waste
		Relevant SDGs:	3,6,12

Scope:

This indicator captures the overall quality of waste generated by the operations of the industry in terms of an impact score. This indicator considers the overall quality of the wastewater and other waste as reported in indicators G4-EN22 and G4-EN23. This indicator therefore rewards industries for discharge of high quality waste and penalises industries that discharge highly contaminated wastewater or hazardous waste.

If indicators G4-EN22 and G4-EN23 are split into several individually weighted indicators to report the discharge of waste of different qualities in a detailed assessment, the present indicator can be removed as to ensure the impact of different qualities of waste discharged by the industry is not double counted.

A.4 Social Indicators

This section first presents the scope statements for all the social indicators, followed by the scope statements for all the social sub-indicators in Section A.4.1.

Indicator ID	*Composed of*	*Indicator Name*	
Soci-1	**Soci-1.1** **Soci-1.2**	**Employment**	
		Measured by:	Number of employees & impact of employment
		Measured aspect:	Employment
		Relevant SDGs:	5,8
Scope: This indicator quantifies the employment expected to be created by an industry in terms of the number of new employee hires and the impact of the employment created.			

Indicator ID	*Composed of*	*Indicator Name*	
Soci-2	**G4-LA6**^{M}	**Health and safety risk**	
		Measured by:	Total rate of injury and occupational disease (occurrences/time)
		Measured aspect:	Occupational health and safety
		Relevant SDGs:	3,8
Scope: This indicator reflects the total includes the injury rate (IR) and the occupational disease rate (ODR) for the total workforce, including total employees, supervised workers and independent contractors working on-site. The injury rate includes fatalities. *For detailed assessment, the injury rate and the occupational disease rate can be reported in separate indicators, thereby allowing different weights to be allocated to the indicators (this is only sensible if injuries and occupational diseases are deemed to be of different levels of importance or significance).*			

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Composed of*	*Indicator Name*	
Soci-3	**G4-LA9**	**Average hours of training for employees**	
		Measured by:	Average hours of training per employee per year
		Measured aspect:	Training and education
		Relevant SDGs:	4,5,8

Scope:

This indicator captures the average hours of training per year per employee (calculated by dividing the total number of training hours provided to employees by the total number of employees). Employee numbers may be expressed as head count or Full Time Equivalent (FTE).
For detailed assessment, the average hours of training can be reported in separate indicators according to different employee categories and/or gender, thereby allowing different weights to be allocated to the different indicators. This is sensible if training of specific employee categories or gender groups are deemed to be of greater significance that others.

Adapted from Global Reporting Initiative (2013a,b,c).

Indicator ID	*Composed of*	*Indicator Name*	
Soci-4	**Soci-4.1 through Soci-4.6**	**Human rights in whole supply chain**	
		Measured by:	Total risk score
		Measured aspect:	Human rights assessments
		Relevant SDGs:	5,8,16

Scope:

This indicator will be the sum of the risk scores of the individual indicators of which it is composed, namely, the risk of negative impacts for labour practices in the supply chain, the risk of incidents of discrimination, the risk of violation of freedom of association, the risk of child-, forced- or compulsory labour and the risk of human rights violations in the supply chain.

Indicator ID	*Composed of*	*Indicator Name*	
Soci-5	**Soci-5.1** **Soci-5.2** **Soci-5.3**	**Negative impacts on local communities**	
		Measured by:	Total risk score
		Measured aspect:	Local communities
		Relevant SDGs:	1,2,16

Scope:

This indicator will be the sum of the risk scores of the individual indicators of which it is composed, namely, the risk of negative impacts on local communities, risks related to corruption and the risk of negative impacts on society in the supply chain.

Indicator ID	*Composed of*	*Indicator Name*	
Soci-6	**Soci-6.1** **Soci-6.2**	**Health and safety impacts of products and services**	
		Measured by:	Total risk score
		Measured aspect:	Customer health and safety
		Relevant SDGs:	None

Scope:

This indicator will be the sum of the risk scores of the individual indicators of which it is composed, namely, the risk of health and safety impacts of products and services and the sale of banned or disputed products.

A.4.1 Social sub-indicators

This section presents the scope statements for the sub-indicators of which the indicators in Section A.4, above, are composed.

Indicator ID	*Derived from*	*Indicator Name*	
Soci-1.1	**G4-LA1**	**Number and rate of new employee hires**	
		Measured by:	Number of employees
		Measured aspect:	Employment
		Relevant SDGs:	5,8

Scope:

This indicator aims to capture the total expected new employment that will be created by development of the industry under consideration. This indicator therefore includes all expected permanently employed personnel as well as independent contractors that is necessary for the day-to-day operation of the industry. Temporary project personnel, such as construction personnel, are not included.
For detailed assessment, the total expected employment can be split into separate indicators according to age and gender. Reporting separate indicators allows different weights to be allocated to the indicators, which may be sensible if employment in different categories are deemed to have different levels of desirability.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-1.2		**Impact of employment**	
		Measured by:	Impact score
		Measured aspect:	Employment
		Relevant SDGs:	5,8

Scope:

This indicator captures the expected impact of the employment an industry is likely to generate in the form of an impact score. The indicator aims to reward industries that are likely to create employment that fit the employment needs of the subject country. The most desirable form of employment will be country-specific. In the case of developing countries with high unemployment levels, creating a large number of jobs might be more desirable than creating fewer highly skilled positions. In other economies and those economies aiming to become knowledge-based, the opposite may be true.

The impact score for this indicator should therefore be based on thorough consideration of the type employment that is desirable in the subject country and whether the type of employment the subject industry is likely to create fits those needs.

Indicator ID	*Derived from*	*Indicator Name*	
Soci-4.1	**G4-LA15**	**Negative impacts for labor practices in the supply chain**	
		Measured by:	Risk score
		Measured aspect:	Supplier assessment for labour practices
		Relevant SDGs:	5,8,16

Scope:

This indicator aims to reflect the risk of negative impacts due to poor labour practices as a qualitative estimate of risk within the supply chain. The nature of the risk is to be quantified with the use of an impact-likelihood matrix. Negative impacts include those that are either caused or contributed to by the industry, or that are linked to its activities, products, or services by relationships with suppliers. Impact assessments for labour practices may include:

- Employment practices
- Health and safety practices
- Incidents (such as of verbal, psychological, physical or sexual abuse, coercion or harassment)
- Industrial relations
- Wages and compensation
- Working hours

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-4.2	**G4-HR3**	**Incidents of discrimination**	
		Measured by:	Risk score
		Measured aspect:	Non-discrimination
		Relevant SDGs:	5,8,16

Scope:

Due to the prospective nature of this framework, it is not possible to assess incidents of discrimination that occurred in the industry. Further, incidents of discrimination are generally organisation-specific. However, incidents of discrimination are more prevalent in some industries than others and the general risk for discrimination may therefore be generalised to a reasonable extent. This indicator therefore aims to capture the expected risk for discrimination for the specific industry being considered. The expected risk can be assessed with the use of a impact-likelihood matrix.
Consider the potential for incidents of discrimination on grounds of race, color, sex, religion, political opinion, national extraction, or social origin as defined by the ILO, or other relevant forms of discrimination involving internal and external stakeholders across operations. Note that this indicator is modified to specifically refer to the industry being considered and not the entire supply chain (impacts in the supply chain is captured in indicator G4-HR11).

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-4.3	**G4-HR4**	**Significant risk of freedom of association in operations and suppliers**	
		Measured by:	Risk score
		Measured aspect:	Freedom of association
		Relevant SDGs:	8

Scope:

This indicator aims to reflect the perceived risk for violation of employees' right to freedom of association and collective bargaining in an industry. Violations of employees' rights in this regard are generally organisation-specific, however, such incidents may be more prevalent in some industries than others and the general risk for such violations may therefore be generalised to a reasonable extent. The perceived risk can be assessed with the use of a impact-likelihood matrix.

The process of identification of operations or suppliers in which these rights of employees may be at significant risk can draw from recognized international data sources such as the ILO Information and reports on the application of Conventions and Recommendations and the ILO Freedom of association - Digest of decisions and principles of the Freedom of Association Committee of the Governing Body of the ILO. Note that this indicator is modified to specifically refer to the industry being considered and not the entire supply chain (impacts in the supply chain is captured in indicator G4-HR11).

Adapted from Global Reporting Initiative (2013a,b,c).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-4.4	**G4-HR5**	**Significant risk of child labour in operations**	
		Measured by:	Risk score
		Measured aspect:	Child labour
		Relevant SDGs:	8,16

Scope:
This indicator aims to reflect the perceived risk for child labour and exposure of young workers to hazardous work in an industry. Incidents regarding child labour and exposure of young workers to hazardous work environments are generally organisation-specific, however, such incidents may be more prevalent in some industries than others and the general risk for such incidents may therefore be generalised to a reasonable extent. The perceived risk can be assessed with the use of a impact-likelihood matrix. The process of identification of operations or suppliers in which a significant risk of child labour and related incidents exist may draw from recognized international data sources such as ILO Information and reports on the application of Conventions and Recommendations.
For detailed assessment, the risk for child labour and the risk for exposure of young workers to hazardous work can be reported in separate indicators, thereby allowing different weights to be allocated to the different indicators. This is sensible if one of these risks are deemed to be of greater significance that the other.
Note that this indicator is modified to specifically refer to the industry being considered and not the entire supply chain (impacts in the supply chain is captured in indicator G4-HR11).

Adapted from Global Reporting Initiative (2013a,b,c).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-4.5	**G4-HR6**	**Significant risk of forced or compulsory labour in operations**	
		Measured by:	Risk score
		Measured aspect:	Forced or compulsory labour
		Relevant SDGs:	8

Scope:

This indicator aims to reflect the perceived risk for forced or compulsory labour in an industry. Incidents regarding forced or compulsory labour are generally organisation-specific, however, such incidents may be more prevalent in some industries than others and the general risk for such incidents may therefore be generalised to a reasonable extent. The perceived risk can be assessed with the use of an impact-likelihood matrix.

The process of identification of operations or suppliers in which a significant risk of forced or compulsory labour and related incidents exist may draw from recognized international data sources such as ILO Information and reports on the application of Conventions and Recommendations.

Note that this indicator is modified to specifically refer to the industry being considered and not the entire supply chain (impacts in the supply chain is captured in indicator G4-HR11).

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-4.6	**G4-HR11**	**Human rights impacts in the supply chain**	
		Measured by:	Risk score
		Measured aspect:	Supplier human rights assessments
		Relevant SDGs:	None

Scope:

Due to the prospective nature of this framework, it is not possible to assess the exact impacts that will occur in the supply chain. Further, the impacts of individual operations may differ. However, negative human rights impacts may be more prevalent in some industries than others and the general risk for such incidents may therefore be generalised to a reasonable extent. This indicator therefore aims to capture the expected impacts of a typical supply chain for the specific industry being considered. The expected risk of negative impacts in the supply chain can be assessed with the use of a impact-likelihood matrix.

Negative impacts include those that are either caused or contributed to by the industry, or that are linked to its activities, products, or services by relationships with suppliers. The human rights impacts considered here may include:

- Child labour
- Discrimination
- Forced or compulsory labor
- Freedom of association and collective bargaining
- Indigenous rights
- Security practices

Note that this indicator reflects the supply chain impacts for the same human rights impacts which are assessed separately for the industry itself (as opposed to the whole supply chain) in indicators G4-LA15, G4-HR3, G4-HR4, G4-HR5 and G4-HR6.

Adapted from Global Reporting Initiative (2013a,b,c).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-5.1	**G4-SO2**	**Negative impacts on local communities**	
		Measured by:	Risk score
		Measured aspect:	Local communities
		Relevant SDGs:	1,2

Scope:

Due to the prospective nature of this framework, it is not possible to assess the exact impacts that will occur in the industry. Further, the impacts of individual operations may differ. However, negative impacts on local communities may be more severe in some industries than others and the general risk for negative impacts on the local community may therefore be generalised to a reasonable extent. This indicator therefore aims to capture the risk of impacts of a specific industry on local communities. The potential negative economic, social, cultural, and environmental impacts on local communities and their rights can be assessed with the use of a impact-likelihood matrix. This may include consideration of:

- Intensity or severity of the impact
- Likely duration of the impact

- Reversibility of the impact
- Scale of the impact

All data collected with indicators in this framework (such as G4-EC8, G4-EN1, G4-EN8, G4-EN20 to G4-EN23, G4-LA7, G4-HR5, G4-HR6, G4-PR1) as related to individual communities may serve as a source of information about the potential negative impacts of operations on local communities. When identifying significant potential negative impacts, consider the vulnerability and risk to local communities from potential impacts due to factors, such as:

- Degree of physical or economic isolation of the local community
- Level of socio-economic development including the degree of gender equality within the community
- State of socio-economic infrastructure (health, education)
- Proximity to operations
- Level of social organization
- Strength and quality of the governance of local and national institutions around local communities

Assess the exposure of the local community to the industry's operations due to higher than average use of shared resources or impact on shared resources. This may include:

- Use of hazardous substances that impact on the environment and human health in general, and specifically reproductive health
- Volume and type of pollution released
- Status as major employer in the local community
- Land conversion and resettlement
- Natural resource consumption

Note that this indicator is modified to specifically refer to the industry being considered and not the entire supply chain (impacts in the supply chain is captured in indicator G4-SO10). Include the expected effects of infrastructure development on the local communities (refer to indicator G4-EC7).

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-5.2	**G4-SO3**	**Risks related to corruption**	
		Measured by:	Risk score
		Measured aspect:	Anti-corruption
		Relevant SDGs:	16

Scope:

Risks related to corruption are generally organisation-specific, however, risk of corruption may be more significant for some industries compared to others. The general perceived risk of corruption may therefore be generalised to a reasonable extent for an industry. This indicator therefore aims to quantify the expected risks related to corruption for the specific industry being considered. The expected risks can be assessed with the use of a impact-likelihood matrix.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-5.3	**G4-SO10**	**Negative impacts on society in the supply chain**	
		Measured by:	Risk score
		Measured aspect:	Supplier assessment for impacts on society
		Relevant SDGs:	None

Scope:

Due to the prospective nature of this framework, it is not possible to assess the exact impacts that will occur in the supply chain. Further, the impacts of individual operations may differ. However, negative impacts on society may be more prevalent in some industries than others and the general risk for such negative impacts may therefore be generalised to a reasonable extent. This indicator therefore aims to capture the expected negative impacts of a typical supply chain, for the specific industry being considered, on society. The expected risk of negative impacts on society in the supply chain can be assessed with the use of a impact-likelihood matrix. Negative impacts include those that are either caused or contributed to by the industry, or that are linked to its activities, products, or services by relationships with suppliers.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-6.1	**G4-PR1**	**Health and safety impact assessments of products and services**	
		Measured by:	Risk score
		Measured aspect:	Customer health and safety
		Relevant SDGs:	None

Scope:

The health and safety impacts of products and services may be organisation-specific, however, some of these impacts may be generalisable for all similar products and services, regardless of the organisation producing it. These general health and safety impacts related to the products and services of some industries may be more prominent in some industries that in others. This indicator therefore aims to capture the perceived risk of negative health and safety impacts related to products and services of the specific industry being considered. The perceived risk can be quantified with the use of a impact-likelihood matrix.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

Indicator ID	*Derived from*	*Indicator Name*	
Soci-6.2	**G4-PR6**	**Sale of banned or disputed products**	
		Measured by:	Risk score
		Measured aspect:	Marketing and communications
		Relevant SDGs:	None

Scope:

This indicator aims to reflect whether an industry to be established will sell products that are:

- Banned in certain markets
- The subject of stakeholder questions or public debate

In order to quantify this indicator and allow summation with indicator G4-PR1 an impact-likelihood matrix is once again used.

Adapted from Global Reporting Initiative (2013*a*,*b*,*c*).

A.5 Indicators excluded

This section presents the GRI G4 indicators not included in the present framework (as discussed in Section 3.3.2 in Chapter 3 of this document) along with a short reason for the exclusion of each. Section A.5.1 presents the indicators excluded in the sieving process, followed by Section A.5.2 that presents the indicators excluded because they were deemed excessive for the present framework.

A.5.1 Indicators excluded during sieving

This section presents the indicators that were excluded from the present framework based on the two sieving criteria, as described in Section 3.3.2. A short reason for the exclusion is provided for each indicator.

A.5.1.1 Economic indicators

Indicator ID	*Derived from*	*Indicator Name*
G4-EC3		**Benefit plan coverage**
		Measured aspect: Economic performance
Indicator not generalisable:		
Within the scope of the presents study, organisational benefit plan coverage cannot be generalised for an entire industry as specific organisations offer different benefit plans and manage these in different ways.		

Indicator ID	*Derived from*	*Indicator Name*
G4-EC5		**Ratio of entry level wage to local minimum wage**
		Measured aspect: Market presence
Indicator not generalisable:		
Due to different business models, -strategies and -management styles, the entry level wage paid to employees by organisations can vary widely within an industry and cannot be generalised with reasonable certainty for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-EC6^M		**Proportion of senior management hired from the local community**
		Measured aspect: Market presence
Indicator not generalisable: Due to different business models, -strategies and -management styles, the composition of senior management of organisations can vary widely within an industry and cannot be generalised with reasonable certainty for an industry.		

A.5.1.2 Environmental indicators

Indicator ID	*Derived from*	*Indicator Name*
G4-EN2^{M}		**Recycled input materials**
		Measured aspect: Materials

Indicator not generalisable:

The portion of recycled input material used varies between different organisations in an industry and cannot be generalised with certainty for an entire industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN6		**Energy reductions**
		Measured aspect: Energy

Indicator not generalisable:

Reduction in energy use is dependent on specific energy saving steps implemented by an organisation and can therefore not be generalised for an industry.

Indicator not applicable to a new industry:

Reduction in energy use cannot be calculated for an industry that is yet to be established.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN7		**Energy reductions in products and services**
		Measured aspect: Energy

Indicator not generalisable:

Reduction in energy use by products and services is dependent on specific energy saving steps implemented by an organisation and can therefore not be generalised for an industry.

Indicator not applicable to a new industry:

Reduction in energy use by products and services cannot be calculated for an industry that is yet to be established.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN9		**Water sources affected by withdrawals**
		Measured aspect: Water
Indicator not generalisable: Specific water sources affected by operations of different organisations will differ and cannot be assumed to be similar throughout an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-EN10		**Water recycled and reused**
		Measured aspect: Water
Indicator not generalisable: The amount of water recycled and reused by different organisations will differ and this indicator can therefore not be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-EN11		**Facilities in or near areas of high biodiversity**
		Measured aspect: Biodiversity
Indicator not generalisable: The location of facilities is organisation specific and can therefore not be assumed to be similar throughout an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-EN12^{M}		**Impacts on biodiversity**
		Measured aspect: Biodiversity
Indicator not generalisable: The organisation-dependent size, location and management of operations will influence the impact on biodiversity and this indicator can therefore not be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-EN13		**Habitats protected or restored**
		Measured aspect: Biodiversity

Indicator not generalisable:

The organisation-dependent size, location and management of operations will influence the protection and restoration of habitat and this indicator can therefore not be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN14		**IUCN Red List species**
		Measured aspect: Biodiversity

Indicator not generalisable:

Red list species affected depends on location of operations and cannot be generalised for an entire industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-MM1^{M}		**Land disturbed or rehabilitated**
		Measured aspect: Biodiversity

Indicator not generalisable:

The typical size of land required for conventional production processes used to produce a specific product can be approximated to some extent, but the specific design of operations and utilities will differ between organisations. Due to the inherent uncertainty regarding the typical amount of land used, this indicator will not be included in the present framework. Note that this indicator also requires the amount of newly disturbed land and rehabilitation of land, which cannot be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-MM2^{M}		**Biodiversity management**
		Measured aspect: Biodiversity

Indicator not generalisable:

Requirements for biodiversity management is dependent on the location, size and management of operations and can therefore not be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN16		**GHG emissions (Scope 2)**
		Measured aspect: Emissions

Indicator not generalisable:

Indirect greenhouse gas emissions will differ for different organisations, as each organisation will have a unique distribution of own generation and purchased energy. Indirect emissions is therefore not generalisable, but will be included in indicator G4-EN15 (as explained in the scope statement for G4-EN15).

Indicator ID	*Derived from*	*Indicator Name*
G4-EN19		**Reduction of GHG emissions**
		Measured aspect: Emissions

Indicator not generalisable:

Reductions in greenhouse gas emissions due to organisation-specific initiatives to reduce emissions cannot be generalised for an industry as different organisations implement different initiatives resulting in different reductions.

Indicator not applicable to a new industry:

Reduction in greenhouse gas emissions cannot be calculated for an industry that is yet to be established.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN24^{M}		**Significant spills**
		Measured aspect: Effluents & waste

Indicator not generalisable:

Spills are organisation specific and depend on management of individual operations. This indicator can therefore not be generalised with reasonable certainty for an industry.

Indicator not applicable to a new industry:

Spills cannot be used for an industry that is yet to be established.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN25		**Hazardous waste**
		Measured aspect: Effluents & waste

Indicator not generalisable:

The mass of hazardous waste generated is included in EN23, above. This indicator specifically refers to the transport, import, export and treatment of hazardous waste. These actions will be organisation-specific and cannot be generalised for all organisations in an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN26		**Biodiversity affected by runoff**
		Measured aspect: Effluents & waste

Indicator not generalisable:

Habitats affected by run-off is dependent on the location, nature and waste management of individual operations and this indicator can therefore not be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN27		**Mitigation of environmental impacts of products and services**
		Measured aspect: Products & services

Indicator not generalisable:

Mitigation of impacts depend on organisation-specific initiatives and can therefore not be generalised for an industry.

Indicator not applicable to a new industry:

Mitigation of environmental impacts of products and services cannot be used for an industry that is yet to be established.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN29		**Environmental fines & sanctions**
		Measured aspect: Compliance

Indicator not generalisable:

Fines and sanctions are organisation-specific and cannot be generalised for an industry.

Indicator not applicable to a new industry:

Fines and sanctions cannot be used for an industry that is yet to be established.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN30		**Environmental impacts from product distribution and employee travel**
		Measured aspect: Transport

Indicator not generalisable:

Material, product and employee transport is highly dependent on the location of operations and the management of an organisation. This indicator can therefore not be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN31		**Environmental investments**
		Measured aspect: Environmental investments

Indicator not generalisable:

Environmental protection expenditure is organisation-specific and cannot be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN32		**New suppliers screened using environmental criteria**
		Measured aspect: Supplier environmental

Indicator not generalisable:

Contracting and screening of suppliers is organisation-specific and cannot be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN34		**Environmental grievances**
		Measured aspect: Environmental grievance mechanisms

Indicator not generalisable:

Grievances result from organisation-specific action or lack of action and can therefore not be generalised for an industry.

Indicator not applicable to a new industry:

Grievances cannot be used for an industry that is yet to be established.

A.5.1.3 Social indicators

Indicator ID	*Derived from*	*Indicator Name*
G4-LA2		**Benefits provided to full-time employees**
		Measured aspect: Employment
Indicator not generalisable: Benefits provided to full-time employees that are not provided to temporary or part-time employees cannot be generalised for an entire sector (similar to G4-EC3).		

Indicator ID	*Derived from*	*Indicator Name*
G4-LA3		**Return to work and retention rates after parental leave**
		Measured aspect: Employment
Indicator not generalisable: Retention rates after parental leave depends on the organisation-specific work environment and can therefore not be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-LA4		**Notice periods regarding operational changes**
		Measured aspect: Labour/Management relations
Indicator not generalisable: Notice periods regarding operational changes depend on specific organisation policy and cannot be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-MM4^{M}		**Number of strikes and lock-outs**
		Measured aspect: Labour/Management relations
Indicator not generalisable: The number of strikes and lock-outs are dependent on organisation-specific factors and cannot be generalised for an industry. *Indicator not applicable to a new industry:* Strikes and lock-outs cannot have taken place if the industry is yet to be established and this indicator is therefore not applicable for the present project.		

Indicator ID	*Derived from*	*Indicator Name*
G4-LA5		**Workforce represented in health and safety committees**
		Measured aspect: Occupational health & safety
Indicator not generalisable: Workforce representation in health and safety committees will differ for different organisations and cannot be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-LA8		**Health & safety topics covered in agreements with trade unions**
		Measured aspect: Occupational health & safety
Indicator not generalisable: Health and safety agreements with trade unions are organisation-specific and cannot be generalised with certainty for an entire industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-LA10		**Programs for skills management managing career endings**
		Measured aspect: Training & education
Indicator not generalisable: Skills management programs depend on organisation-specific policy and cannot be generalised for an industry consisting of different organisations.		

Indicator ID	*Derived from*	*Indicator Name*
G4-LA11		**Employees receiving performance and career development reviews**
		Measured aspect: Training & education

Indicator not generalisable:

Employee performance and career reviews depend on organisation-specific policy regarding employee development and may differ substantially between organisations in a specific industry, therefore making accurate generalisation impossible.

Indicator ID	*Derived from*	*Indicator Name*
G4-LA12		**Composition of governance bodies and employees**
		Measured aspect: Diversity

Indicator not generalisable:

Diversity of governance bodies and employees within an industry depend on the diversity of the organisations the industry is composed of and the diversity of the industry can therefore not be generalised with certainty without an assessment of the individual organisations.

Indicator ID	*Derived from*	*Indicator Name*
G4-LA13		**Ratio of basic salary & remuneration of women to men**
		Measured aspect: Equal pay for women & men

Indicator not generalisable:

The ratio of basic salary and remuneration of women to men depend on organisation-specific efforts to ensure equal payment for work of equal value. This indicator can therefore not be sensibly generalised for an entire industry.

<table>
<tr><td>Indicator ID
G4-LA14</td><td>Derived from</td><td>Indicator Name
New suppliers that were screened using labour practices criteria
Measured aspect: Supplier assessment for labour practices</td></tr>
<tr><td colspan="3">Indicator not generalisable:
Contracting and screening of suppliers is organisation-specific and cannot be generalised for an industry.</td></tr>
</table>

<table>
<tr><td>Indicator ID
G4-LA16</td><td>Derived from</td><td>Indicator Name
Grievances about labour practices
Measured aspect: Labour practices grievances mechanisms</td></tr>
<tr><td colspan="3">Indicator not generalisable:
Grievances result from organisation-specific action or lack of action and can therefore not be generalised for an industry.
Indicator not applicable to a new industry:
Grievances cannot be used for an industry that is yet to be established.</td></tr>
</table>

<table>
<tr><td>Indicator ID
G4-HR1</td><td>Derived from</td><td>Indicator Name
Investment agreements and contracts that include human rights clauses and underwent screening
Measured aspect: Human rights investments</td></tr>
<tr><td colspan="3">Indicator not generalisable:
Investment agreements and its inclusions are organisation-specific and cannot be generalised for an industry.</td></tr>
</table>

<table>
<tr><td>Indicator ID
G4-HR2</td><td>Derived from</td><td>Indicator Name
Employee training on human rights
Measured aspect: Human rights investments</td></tr>
<tr><td colspan="3">Indicator not generalisable:
Time spent on employee training on human rights is dependent on organisation-specific policy and can therefore not be generalised for an industry, unless specific regulations enforce specific human rights training requirements.</td></tr>
</table>

Indicator ID	*Derived from*	*Indicator Name*
G4-HR7		**Security personnel trained in the organisation's human rights policies**
		Measured aspect: Security practices
Indicator not generalisable:		
Training of security personnel in human rights is dependent on organisation-specific policy and can therefore not be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-HR8		**Incidents of violations involving rights of indigenous peoples**
		Measured aspect: Indigenous Rights
Indicator not generalisable:		
Incidents of violation involving rights of indigenous peoples depend on the location, nature and size of operations and organisation policy. This indicator can therefore not be generalised for an industry.		
Indicator not applicable to a new industry:		
Incidents of violation of rights of indigenous people cannot have taken place if an industry is yet to be established and this indicator can therefore not be used in the framework.		

Indicator ID	*Derived from*	*Indicator Name*
G4-MM5^{M}		**Operations taking place in or adjacent to indigenous peoples' territories**
		Measured aspect: Indigenous Rights
Indicator not generalisable:		
The number of operations taking place in or adjacent to indigenous peoples' territories cannot be generalised for an industry as the location of operations differ according to the organisations of which the industry is composed.		
Indicator not applicable to a new industry:		
The location of operations cannot be used as the industry and its operations is not yet established.		

Indicator ID	*Derived from*	*Indicator Name*
G4-HR10		**New suppliers screened for human rights**
		Measured aspect: Supplier Human Rights Assessment
Indicator not generalisable: Contracting and screening of suppliers is organisation-specific and cannot be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-HR12		**Grievances about human rights**
		Measured aspect: Human rights grievances mechanisms
Indicator not generalisable: Grievances result from organisation-specific action or lack of action and can therefore not be generalised for an industry. *Indicator not applicable to a new industry:* Grievances cannot be used for an industry that is yet to be established.		

Indicator ID	*Derived from*	*Indicator Name*
G4-SO1		**Local community engagement, impact assessments and development programs**
		Measured aspect: Local communities
Indicator not generalisable: Implementation of local community engagement, impact assessments and development programs are dependent on organisation-specific policy and strategy and cannot be generalised for an industry consisting of different organisations with different policies and strategies.		

Indicator ID	*Derived from*	*Indicator Name*
G4-MM6^{M}		**Disputes relating to land use, customary rights of local communities and indigenous peoples**
		Measured aspect: Local communities

Indicator not generalisable:

Disputes relating to land use, customary rights of local communities and indigenous peoples are dependent on the location, size and nature of operations and are therefore organisation-specific and not generalisable.

Indicator ID	*Derived from*	*Indicator Name*
G4-MM7^{M}		**Grievance mechanisms used to resolve disputes**
		Measured aspect: Local communities

Indicator not generalisable:

Grievances result from organisation-specific action or lack of action and can therefore not be generalised for an industry.

Indicator not applicable to a new industry:

Grievances cannot be used for an industry that is yet to be established.

Indicator ID	*Derived from*	*Indicator Name*
G4-SO4		**Communications & training on anti-corruption**
		Measured aspect: Anti-corruption

Indicator not generalisable:

Communications and training on anti-corruption is organisation-specific and cannot be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-SO5		**Confirmed incidents of corruption**
		Measured aspect: Anti-corruption

Indicator not generalisable:

Incidents of corruption are inherently organisation-specific and can therefore not be generalised for an industry. Risk of corruption is captured in SO3.

Indicator not applicable to a new industry:

Incidents of corruption cannot have taken place if an industry is yet to be established and this indicator can therefore not be used in the framework.

Indicator ID	*Derived from*	*Indicator Name*
G4-SO6		**Political contributions**
		Measured aspect: Public policy
Indicator not generalisable: Political contributions made by organisations depend on organisation-specific political affiliations and cannot be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-SO7		**Anti-competitive behaviour**
		Measured aspect: Anti-competitive behaviour
Indicator not generalisable: Legal action regarding anti-competitive behaviour result from organisation-specific action or lack of action and can therefore not be generalised. *Indicator not applicable to a new industry:* Anti-competitive behaviour, anti-trust and monopoly practices, and the subsequent legal action, cannot have taken place an industry that is yet to be established.		

Indicator ID	*Derived from*	*Indicator Name*
G4-SO8^{M}		**Fines for non-compliance with laws**
		Measured aspect: Compliance
Indicator not generalisable: Fines and sanctions are organisation-specific and cannot be generalised for an industry. *Indicator not applicable to a new industry:* Fines and sanctions cannot be used for an industry that is yet to be established.		

Indicator ID	*Derived from*	*Indicator Name*
G4-SO9		**New suppliers screened for impacts on society**
		Measured aspect: Supplier assessment for impacts on society
Indicator not generalisable: Contracting and screening of suppliers is organisation-specific and cannot be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-SO11		**Grievances about impacts on society**
		Measured aspect: Grievance mechanisms for impacts on society
Indicator not generalisable: Grievances result from organisation-specific action or lack of action and can therefore not be generalised for an industry. *Indicator not applicable to a new industry:* Grievances cannot be used for an industry that is yet to be established.		

Indicator ID	*Derived from*	*Indicator Name*
G4-MM8^{M}		**Operating sites where artisanal or small-scale mining takes place on or adjacent to**
		Measured aspect: Artisanal & small-scale mining
Indicator not generalisable: Operating sites close to artisanal or small-scale mining and the risks related to this proximity are dependent on the location, size and nature of operations and are therefore organisation-specific and not generalisable.		

Indicator ID	*Derived from*	*Indicator Name*
G4-MM9^{M}		**Sites where resettlements took place**
		Measured aspect: Resettlement
Indicator not generalisable: Sites where resettlements took place and the impacts the resettlement had on the livelihoods of the affected parties are dependent on the location of operations and are therefore organisation-specific and not generalisable.		

Indicator ID	*Derived from*	*Indicator Name*
G4-MM10^{M}		**Operations with closure plans**
		Measured aspect: Closure planning
Indicator not generalisable: Whether closure plans are in place for operations depend on organisation-specific strategy, policy and initiative and cannot be generalised for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-PR2		**Non-compliance concerning the health & safety impacts of products & services**
		Measured aspect: Customer health & safety

Indicator not generalisable:

Incidents of non-compliance with regulations result from inadequate internal management systems and procedures, or ineffective implementation. This indicator is therefore organisation-specific and not generalisable for an industry.

Indicator not applicable to a new industry:

Incidents of non-compliance with regulations cannot have taken place if an industry is yet to be established and this indicator can therefore not be used.

Indicator ID	*Derived from*	*Indicator Name*
G4-PR3		**Product & service information required for labelling**
		Measured aspect: Product & service labelling

Indicator not generalisable:

Product and service information and labelling is based on organisation-specific policy, but may be enforced by regulations for specific industries and can only in such cases be generalised for an industry.

Indicator ID	*Derived from*	*Indicator Name*
G4-PR4		**Non-compliance with regulations concerning product & service labelling**
		Measured aspect: Product & service labelling

Indicator not generalisable:

Non-compliance with regulations results from inadequate internal management systems and procedures and is organisation-specific and is therefore not generalisable.

Indicator not applicable to a new industry:

Incidents of non-compliance with regulations cannot have taken place if an industry is yet to be established and this indicator can therefore not be used.

Indicator ID	*Derived from*	*Indicator Name*
G4-PR5		**Surveys measuring customer satisfaction**
		Measured aspect: Product & service labelling
Indicator not generalisable: Customer satisfaction surveys are conducted by some organisations only and depend on the relationship between the specific organisation and its stakeholders. This indicator can therefore not be generalised sensibly for an industry.		

Indicator ID	*Derived from*	*Indicator Name*
G4-PR7		**Non-compliance with regulations concerning marketing communications**
		Measured aspect: Marketing & communications
Indicator not generalisable: Non-compliance with regulations results from inadequate internal management systems and procedures and is organisation-specific and is therefore not generalisable.		
Indicator not applicable to a new industry: Incidents of non-compliance with regulations cannot have taken place if an industry is yet to be established and this indicator can therefore not be used.		

Indicator ID	*Derived from*	*Indicator Name*
G4-PR8		**Complaints regarding breaches of customer privacy & losses of customer data**
		Measured aspect: Customer privacy
Indicator not generalisable: Complaints regarding breaches of customer privacy and non-compliance with regulations results from inadequate internal management systems and procedures and is organisation-specific and is therefore not generalisable.		
Indicator not applicable to a new industry: Complaints regarding breaches of customer privacy and losses of customer data cannot be used for an industry that is yet to be established.		

Indicator ID	*Derived from*	*Indicator Name*
G4-PR9		**Fines for non-compliance with laws and regulations concerning products & services**
		Measured aspect: Product compliance

Indicator not generalisable:

Fines and sanctions are organisation-specific and cannot be generalised for an industry.

Indicator not applicable to a new industry:

Fines and sanctions cannot be used for an industry that is yet to be established.

A.5.2 Indicators deemed excessive

This section presents the 5 indicators that were excluded from the present framework because they were deemed excessive, although they were acceptable based on the two initial sieving criteria, as described in Section 3.3.2. The reasons for the exclusions are presented below.

Indicator ID	*Derived from*	*Indicator Name*
G4-EN5		**Energy intensity**
		Measured aspect: Energy
Indicator excessive: This indicator will not be used as it only presents the information presented by G4-EN3 and G4-EN4 in a different form and is therefore deemed excessive for the present framework.		

Indicator ID	*Derived from*	*Indicator Name*
G4-EN18		**GHG emissions intensity**
		Measured aspect: Emissions
Indicator excessive: This indicator will not be used as it only presents the information presented by G4-EN15 and G4-EN17 in a different form and is therefore deemed excessive for the present framework.		

Indicator ID	*Derived from*	*Indicator Name*
G4-MM3		**Amounts of overburden, rock, tailings and sludges**
		Measured aspect: Effluents and waste
Indicator excessive: This indicator will not be used, as this framework specifically aims to evaluate the sustainability implications of beneficiating a metal by manufacturing a specific product and comparing these implications to that of other products that can be manufactured with the metal. The source of the metal is therefore assumed to be similar for all the products, implying that theoretically the amount of mining and mineral processing waste generated to produce that metal is the same or similar for all products that can be manufactured with the metal and it is therefore not sensible to include this indicator in the present framework. Note that the material use (including the amount of metal used) is captured in indicator EN1.		

Indicator ID	*Derived from*	*Indicator Name*
G4-LA7		**Workers with high incidence of risk of diseases**
		Measured aspect: Occupational health and safety

Indicator excessive:

This indicator aims to reflect whether there are workers who are involved in occupational activities who have a high incidence or high risk of specific diseases. This information is already captured in the occupational disease rate in indicator G4-LA6. Further, this indicator is qualitative, with no specific rate that is reported. Quantification and summation with G4-LA6 is therefore problematic and subsequently this indicator is not included in the present framework.

Indicator ID	*Derived from*	*Indicator Name*
G4-HR9		**Operations that have been subject to human rights assessments**
		Measured aspect: Human rights assessments

Indicator excessive:

In the GRI G4 framework, this indicator seeks to reflect the extent to which an organization takes human rights considerations into account in its decision-making. This cannot be reported in the present framework, due to its prospective nature. This indicator will therefore have to be modified to reflect the perceived risk of human rights violations, however, this information is already captured in the modified indicators G4-LA15, G4-HR3, G4-HR4, G4-HR5 and G4-HR6. This indicator is therefore excluded from this framework.

Appendix B

Additional documents regarding framework validation

This appendix presents the questionnaire (Section B.1) and written consent form (Section B.2) used in the framework validation process, as discussed in Section 3.3.7 in Chapter 3. The letter of approval of the ethical clearance application to contact the experts to validate the framework is presented in Section B.3.

B.1 Questionnaire

Comparing sustainable development potential of metal beneficiation industries by using publicly available sustainability information

Assessment framework validation

Purpose

This questionnaire serves to evaluate the potential utility and perceived shortcomings of the attached assessment framework.

The framework was developed with the aim of providing high level guidance during scoping phase decision-making by policymakers in the process of assessing the feasibility of potential development opportunities and determining which opportunities warrant further investigation.

Description

The framework makes use of publicly available organizational sustainability information reported according to the Global Reporting Initiative (GRI) G4 Sustainability Reporting Guidelines. This organization-level information is scaled in order to assess and compare development opportunities at industry-level. Figure 1, below, illustrates the comparison of different development opportunities as facilitated by the developed framework.

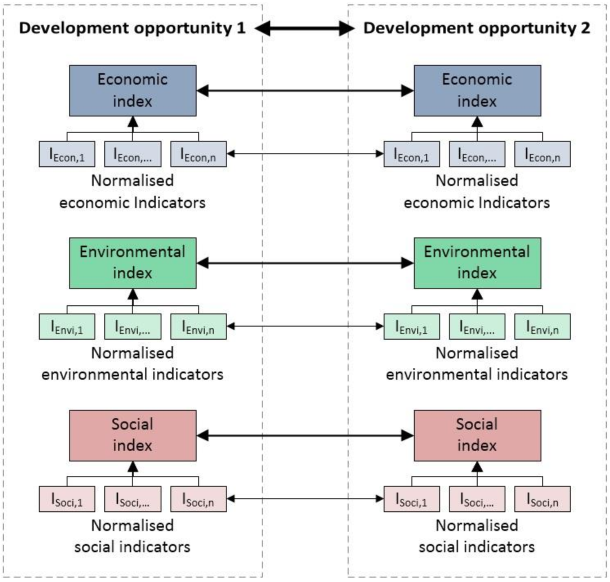


Figure 1: Comparison of potential development opportunities

The framework makes use of 6 economic-, 6 environmental- and 6 social indicators, each comprised of sub-indicators (kindly refer to the table at the end of this document). The indicators are aggregated into a single composite index for each sustainability dimension (economic, environmental and social), allowing easy comparison of different development opportunities at the hand of only 3 index values. The index values can be analyzed in order to establish which indicators or sub-indicators are specifically responsible for significant differences in the index values for different development opportunities, allowing identification of specific aspects that contribute significantly to the relative superiority or inferiority of a specific development opportunity.

The indicators and sub-indicators used in the framework are summarized in the table at the end of this document.

Questions

Please evaluate the attached indicator framework by answering the following questions in the spaces provided.

Respondent's name:	
Organisation/Company:	
Job title:	

1. Are the indicators considered in the framework comprehensive enough to ensure accurate comparison of development opportunities? If not, please explain the shortcomings briefly.

2. Do you believe the framework has potential to be useful as a high level comparison tool for policymakers that need to decide which development opportunities should be prioritised? Please explain briefly.

3. Do you believe the use of publicly available sustainability information in the framework is an innovative way to make use of the growing amount of such sustainability information that is available in the public domain? Please explain briefly.

4. What are the shortcomings of the framework? Please explain briefly.

Aspects	GRI ID[1]	ID	Impact	Indicator	Measurement unit
Economic Indicators					
Economic Performance	**G4-EC1**	**Econ-1**	**+**	**Economic value**	**Expected earnings**
		Econ-2		**Climate change risks**	**Risk score[2]**
	G4-EC2		+/-	Risks and opportunities posed by climate change that may have substantive economic impacts	Risk score
		Econ-3		**Financial assistance from the government**	**Monetary value of assistance**
	G4-EC4		-	Financial assistance expected or required to be provided by government	Monetary value of assistance
Indirect Economic Impacts		**Econ-4**		**Infrastructure investments**	**Monetary value of investment**
	G4-EC7		+	Monetary value of expected infrastructure investments to be made for commercial purposes	Monetary value of investment
	G4-EC8	**Econ-5**	**+/-**	**Indirect economic impacts**	**Monetary value of indirect impacts**
Procurement Practices	**G4-EC9**	**Econ-6**	**+**	**Local suppliers**	**Percentage of operating cost**
Environmental Indicators					
Materials		**Envi-1**		**Materials consumption (water included)**	**Mass of material**
	G4-EN1		-	Materials by weight or volume	Mass of material
	G4-EN8		-	Water withdrawals by source	Mass of water
Energy		**Envi-2**		**Total energy consumption**	**Joules (or multiples) of energy**
	G4-EN3		-	Energy consumption (Scope 1 + 2)	Joules (or multiples) of energy
	G4-EN4		-	Energy consumption (Scope 3)	Joules (or multiples) of energy
Emissions		**Envi-3**		**Total gaseous emissions**	**Mass of gaseous emissions**
	G4-EN15		-	Greenhouse gas emissions (Scope 1 + 2)	Mass of CO2 equivalent
	G4-EN17		-	Greenhouse gas emissions (Scope 3)	Mass of CO2 equivalent
	G4-EN20		-	Ozone-depleting substances (ODS)	Mass of CFC-11 equivalent
	G4-EN21		-	NOx, SOx and other emissions	Mass of noxious gas emissions
Effluents & Waste		**Envi-4**		**Total waste discharge (including water, hazardous waste and normal process waste)**	**Mass of waste discharge**
	G4-EN22		-	Water discharge	Mass of water discharge
	G4-EN23		-	Waste by type and disposal method	Mass of waste generated
Products & Services	**G4-EN28**	**Envi-5**	**+**	**Products and packaging materials reclaimed**	**Percentage reclaimed**
Supplier environmental	**G4-EN33**	**Envi-6**	**-**	**Supply chain environmental impacts**	**Risk score[2]**
Social Indicators					
Sub-category: Labor Practices & Decent Work					
Employment		**Soci-1**		**Total employment**	**Number of employees**
	G4-LA1		+	Number and rate of new employee hires and turnover	Number of employees
Occupational health & safety		**Soci-2**	-	**Health & safety risk**	**Total rate of injury and occupational disease (occurrences/time)**
	G4-LA6		-	Rates of injury, occupational disease, lost days, absenteeism, and work-related fatalities	Total rate of injury and occupational disease (occurrences/time)
Training & Education		**Soci-3**		**Average hours of training for employees**	**Average hours of training per employee per year**
	G4-LA9		+	Average hours of training for employees	Average hours of training per employee per year
Sub-category: Human Rights					
Human Rights Assessments		**Soci-4**		**Human rights in whole supply chain**	**Total risk score**
Supplier Assessment for labour practices	G4-LA15		-	Negative impacts for labour practices in the supply chain	Risk score[2]
Non-discrimination	G4-HR3		-	Incidents of discrimination	Risk score[2]
Freedom of Association	G4-HR4		-	Significant risk of freedom of association in operations and suppliers	Risk score[2]
Child Labour	G4-HR5		-	Significant risk of child labour in operations and suppliers	Risk score[2]
Forced or Compulsory Labour	G4-HR6		-	Significant risk of forced or compulsory labour in operations and suppliers	Risk score[2]
Supplier Human Rights Assessments	G4-HR11		-	Human rights impacts in the supply chain	Risk score[2]
Sub-category: Society					
Local communities		**Soci-5**		**Negative impacts on local communities**	**Total risk score**
Local communities	G4-SO2		-	Negative impacts on local communities	Risk score[2]
Anti-corruption	G4-SO3		-	Risks related to corruption	Risk score[2]
Supplier Assessment for Impacts on Society	G4-SO10		-	Negative impacts on society in the supply chain	Risk score[2]
Sub-category: Product Responsibility					
Customer Health & Safety		**Soci-6**		**Health and safety impact assessments of products and services**	**Total risk score**
Customer Health & Safety	G4-PR1		-	Health and safety impact assessments of products and services	Risk score[2]
Marketing & Communications	G4-PR6		-	Sale of banned or disputed products	Risk score[2]

[1] Identification code as used in the GRI G4 Sustainability Reporting Guidelines
[2] Perceived risk is quantified by allocating a risk score based on an impact-likelihood matrix illustrated in Figure 2

Potential impact	5	6	7	8	9
	4	5	6	7	8
	3	4	5	6	7
	2	3	4	5	6
	1	2	3	4	5
	Likelihood				

Figure 2: Impact-likelihood matrix used to quantify risk

B.2 Written consent

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STELLENBOSCH UNIVERSITY
WRITTEN INFORMATION & CONSENT TO PARTICIPATE IN RESEARCH

TITLE OF RESEARCH PROJECT:	Comparing sustainable development potential of metal beneficiation industries by using publicly available sustainability information
REFERENCE NUMBER:	SU-HSD-000921
RESEARCHER:	Johan du Plessis
ADDRESS:	Department of Industrial Engineering, Stellenbosch University, Private Bag X1, Matieland, 7602
CONTACT NUMBER:	+27 74 3456641
EMAIL:	16443152@sun.ac.za

Dear prospective participant

My name is Johan du Plessis and I would like to invite you to participate in a research project entitled **Comparing sustainable development potential of metal beneficiation industries by using publicly available sustainability information.**

Please take some time to read the information presented here, which will explain the details of this project and contact me if you require further explanation or clarification of any aspect of the study. This study has been approved by the Research Ethics Committee (REC) at Stellenbosch University and will be conducted according to accepted and applicable national and international ethical guidelines and principles.

Introduction

With sustainable business strategies and sustainability reporting now a norm, the public domain has in recent years been flooded with sustainable development information from a wide range of organizations. An opportunity exists to make use of this information to compare the sustainable development potential of different development opportunities prospectively, based on the performance of similar industries elsewhere. A tool that makes use of such sustainability information to compare development opportunities can be used to enhance scoping phase decision-making by policymakers, ultimately allowing policymakers to prioritize projects that have the most potential for creating sustainable outcomes.

Purpose

The aim of the study is therefore to develop a framework that allows the high level comparison of development opportunities and thereby enhance scoping phase decision-making by policymakers. Industrialisation and development of local metal beneficiation industries remain key priorities in South African development strategies and, subsequently, the utility of the framework developed in this study will be illustrated by comparison of potential platinum beneficiation industries that can be developed in South Africa.

Procedures

Upon completion of the development of the aforementioned framework, relevant industry experts (such as yourself) will be contacted in order to review and validate its utility as well as possible shortcomings and improvements. The scope of the required review and validation will be limited to only key aspects, which will be outlined in the accompanying questionnaire. The author can be contacted prior to completion of this consent form if clarification of the purpose and scope of the validation is required.

Time

The time required for participation will depend on the aspects that have to be reviewed and validated by the specific participant, but the scope of the review and validation will be kept to an absolute minimum as far as possible. Multiple rounds of review and validation will be avoided.

Risks

The time consumed during completion of the questionnaire may discomfort some participants. Participants are warned to not disclose organisational information (knowingly or unknowingly) that is deemed confidential without the necessary consent from the organisation.

Benefits

Participants will not benefit directly from participation in the research, however, this study may result in more extensive and more accurate investment in some, or all, beneficiation industries in South Africa and may therefore have an indirect positive impact on the participant.

Confidentiality and data storage

Contact details of participants as well as details regarding the data collected from each participant will be kept confidential. All contact details and data will be stored on a password-protected computer in locked office in the Faculty of Engineering, as well as on a Google Drive account that is password protected. The computer will not be left unattended without being switched off or locked. Only the author and his supervisor will have access to the stored data.

Participation

Below you will be given the opportunity to participate in the survey and thereby indicate your consent. Note that your indication of your willingness to participate will be recorded solely so that we will know that we should not send you reminders in this regard.

If you choose to participate in the survey, that will be taken to include that you declare:

- I have read the above information and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- All issues related to privacy and the confidentiality and use of the information I provide have been explained to my satisfaction.

Please select one of the options below:

	I accept the invitation to participate and give consent that my responses may be used confidentially and anonymously.
	I decline the invitation to participate.

If you have any questions or concerns about the research, please feel free to contact the author:

Johan du Plessis
Cellphone no.: +27 74 3456641
Email address: 16443152@sun.ac.za

Or the study supervisor:

Wouter Bam
Email address: wouterb@sun.ac.za

RIGHTS OF RESEARCH PARTICPANTS: You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za / 021 808 4622] at the Division for Research Development. You have the right to receive a copy of this Consent form.

Yours sincerely

Johan du Plessis
Author/Principal Investigator

B.3 Ethical clearance

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Approval Notice
New Application

21-Apr-2016
Du Plessis, Johan JA

Proposal #: SU-HSD-000921
Title: Platinum Beneficiation in South Africa: An evaluation of the barriers and opportunities

Dear Mr Johan Du Plessis,

Your **New Application** received on **12-Apr-2016**, was reviewed
Please note the following information about your approved research proposal:

Proposal Approval Period: **21-Apr-2016 -20-Apr-2017**

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**SU-HSD-000921**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

Included Documents:

DESC Report
REC: Humanities New Application

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

Appendix C

Calculations

This appendix presents the calculations of the values of all indicators used in the application of the framework to the case study industries, as described in Chapter 5. Sections C.1 and C.2 present the calculations for the jewellery industry and catalytic converter industry, respectively. Section C.3 then presents the scaling calculations.

The highlight colour shown in Table C.1 indicates, throughout this appendix, an input variable that was varied in the uncertainty analysis (as discussed in Section 5.3 in Chapter 5).

Table C.1: Key for interpreting colours used in tables in this chapter

Colour	**Meaning**
	Identifies a variable that was varied in the uncertainty analysis

All risk- and impact scores were determined based on the impact-likelihood or impact-relevance matrix presented in Figure 3.3 in Chapter 3.

C.1 Platinum jewellery industry

This section presents the calculations for the jewellery industry. Sections C.1.1, C.1.2 and C.1.3 present the calculations for the economic, environmental and social indicators, respectively.

C.1.1 Economic indicators

Table C.2 presents data that was gathered from the annual report of the organisation used to represent the jewellery industry and was used in the calculations that follow.

Table C.2: Background data from the platinum jewellery producing organisation used in calculations

	Description	**Value**	**Notes**
1.	Total net sales	US$4 249 913 000	From annual report 2014
2.	Net earnings	US$484 179 000	From annual report 2014
3.	Net sales of statement, fine & solitaire jewellery	US$930 155 000	From annual report 2014
4.	Net sales of engagement jewellery & wedding bands	US$1 245 101 000	From annual report 2014
5.	Percentage of statement, fine & solitaire jewellery made of platinum	87%	From annual report 2014
6.	Percentage of engagement jewellery & wedding bands made of platinum	92%	From annual report 2014
7.	Average price per platinum statement, fine & solitaire jewellery item	US$5 400	From annual report 2014
8.	Average price per platinum engagement jewellery & wedding band item	US$3 600	From annual report 2014
9.	Total cost of sales	US$1 712 738 000	From annual report 2014
10.	Total selling, general & administrative expenses	US$1 645 746 000	From annual report 2014

Econ-1:

The net sales of only platinum jewellery items can be calculated using values 3 and 4, and percentages 5 and 6 in table C.2:

$$\begin{aligned}
&Net\ sales\ of\ platinum\ statement,\ fine\ \&\ solitaire\ jewellery \\
&\qquad = US\$930\ 155\ 000 \times 87\% \\
&\qquad = US\$809\ 234\ 850 &\text{(C.1)} \\
&Net\ sales\ of\ platinum\ engagement\ jewellery\ \&\ wedding\ bands \\
&\qquad = US\$1\ 245\ 101\ 000 \times 92\% \\
&\qquad = US\$1\ 145\ 492\ 920 &\text{(C.2)}
\end{aligned}$$

Thus,

$$\begin{aligned}
&Net\ sales\ of\ platinum\ jewellery \\
&\qquad = US\$809\ 234\ 850 + US\$1\ 145\ 492\ 920 \\
&\qquad = US\$1\ 954\ 727\ 770 &\text{(C.3)}
\end{aligned}$$

Then, using 1 in table C.2,

$$\begin{aligned}
&Net\ sales\ of\ platinum\ jewellery\ as\ a\ percentage\ of\ total\ sales \\
&\qquad = 100(\frac{US\$1\ 954\ 727\ 770}{US\$4\ 249\ 913\ 000}) \\
&\qquad = \boxed{46\%} &\text{(C.4)}
\end{aligned}$$

Assuming earnings are closely related to sales, the portion of the earnings generated by the sale of platinum jewellery can be estimated by scaling 2 in table C.2 (to account for the uncertainty in this estimate, the percentage calculated in equation C.4 was varied in the uncertainty analysis, as presented in Section 5.3):

$$\begin{aligned}
&Net\ earnings\ from\ platinum\ jewellery\ sales \\
&\qquad = US\$484\ 179\ 000 \times \boxed{46\%} \\
&\qquad = \mathbf{US\$222\ 695\ 885} &\text{(C.5)}
\end{aligned}$$

Econ-2:

Based on the organisation's reponse to the 2015 CDP Climate Change Request, the financial risks and -opportunities posed by climate change is expected to be minimal for the organisation. Therefore, the following risk scores were allocated:

$$\begin{aligned}
Risks &= -1 \\
Opportunities &= 1
\end{aligned}$$

Summing the risks and opportunities to attain an overall score gives

$$Overall = \mathbf{0} \tag{C.6}$$

To account for uncertainty in this quantification, the overall score was varied in the uncertainty analysis, as presented in Section 5.3.

Econ-3:

The potential positive indirect economic impacts of a platinum jewellery industry were considered substantial. To quantify the potential positive impact, the impact was considered high (4 out of 5). This score was allocated as a jewellery industry can be developed in areas of high poverty and can create jobs for low skill employees (making its potential impact high). However, establishing such an industry does not require the development of significant infrastructure and will likely only result in a few upstream-, downstream linkages. Sidestream linkages with the gold industry in South Africa may be significant. The potential high impact will therefore likely only be localised, therefore the relevance was deemed fairly low (2 out of 5).

The potential negative indirect economic impacts of a platinum jewellery industry were considered minimal. A jewellery industry makes use of gemstones (including diamonds) and the history of negative impacts generated by the production of gemstones and diamonds leads the author to believe that development of a jewellery industry may have unexpected social impacts in areas where such gemstones are produced, resulting in negative economic impacts (such as loss of FDI). However, the likelihood of these negative impacts being substantial is very low due to the ever-increasing global focus on careful regulation of the diamond and gemstone industries. The potential impact was therefore given 3 out of 5, while the relevance was given 1 out of 5. Therefore:

$$Positive\ impacts = 5$$
$$Negative\ impacts = -3$$

Summing the potential positive and negative impact scores to attain an overall score gives

$$Overall = \mathbf{2} \tag{C.7}$$

To account for uncertainty in this quantification, the overall score was varied in the uncertainty analysis, as presented in Section 5.3.

Econ-4:

The total operating cost can be calculated as the sum of the cost of sales and selling, general & administrative expenses. Thus, using 9 and 10 in table C.2:

$$\begin{aligned} Total\ operating\ cost &= US\$1\,712\,738\,000 + US\$1\,645\,746\,000 \\ &= US\$3\,358\,484\,000 \end{aligned} \tag{C.8}$$

Also, if it is assumed that the cost of sales and selling, general & administrative expenses are proportional to net sales, the cost of sales and selling, general & administrative expenses attributable to the sale of platinum jewellery can be calculated by using the percentage value calculated in equation C.4 (to account for the uncertainty in this estimate, the percentage value was varied in the uncertainty analysis, as presented in Section 5.3).

$$\begin{aligned} Cost\ of\ sales\ for\ platinum\ only &= US\$1\,712\,738\,000 \times 46\% \\ &= US\$787\,765\,898 \end{aligned} \tag{C.9}$$

$$\begin{aligned} &Selling,\ general\ \&\ administrative\ expenses\ for\ platinum\ only \\ &\qquad = US\$1\,645\,746\,000 \times 46\% \\ &\qquad = US\$756\,953\,238 \end{aligned} \tag{C.10}$$

Summing these values gives an estimate of the operating cost attributable to platinum:

$$\begin{aligned} Operating\ cost\ for\ platinum\ only &= US\$787\,765\,898 + US\$756\,953\,238 \\ &= US\$1\,544\,719\,137 \end{aligned} \tag{C.11}$$

Now, in the calculation of the percentage of operating cost that can be sourced locally, it is assumed that all resources used in the manufacture of platinum jewellery (precious metals, diamonds, labour, electricity etc.) can be sourced locally if this industry is developed in South Africa (almost all these resources are already available or produced for other purposes in South Africa). Further, it is assumed that 70% of selling, general & administrative expenses (attributable to platinum) can be sourced locally (to account for the uncertainty in these assumptions, both these estimates were varied in the uncertainty analysis, as presented in Section 5.3). Then:

$$\begin{aligned} &Percentage\ of\ operating\ cost\ (attributable\ to\ platinum)\ that\ can\ be \\ &sourced\ locally = \frac{1\,(US\$787\,765\,898) + 0.7\,(US\$756\,953\,238)}{US\$1\,544\,719\,137} \\ &\qquad = \mathbf{85\%} \end{aligned} \tag{C.12}$$

Econ-5:

To account for uncertainty, the impact scores for all the sub-indicators of which indicator Econ-5 is composed, were varied in the uncertainty analysis (as presented in Section 5.3).

Econ-5.1: The overall impact of factor conditions in South Africa that enhances the feasibility of a platinum jewellery industry is deemed moderate. South Africa many basic factors (availability of labour, platinum, diamonds and gemstones) enhancing the feasibility of a platinum jewellery industry, but has no significant specialised factors that enhances the feasibility of such an industry. Therefore both the significance (impact) and relevance of these factors were rated 3 out of 5. As a result, the allocated overall impact score was **5**.

Econ-5.2: The overall impact of demand conditions in South Africa that enhances the feasibility of a platinum jewellery industry is deemed minimal. In 2013 China, Japan, North America and Europe accounted for 94% of platinum demand by the jewellery industry. The author has no reason to believe that the demand for platinum jewellery in South Africa is significant in terms of the 6% spread over the rest of the world. The author further also has no reason to believe that the character of demand in South Africa is sophisticated. Thus, the impact was rated 2 out of 5, while the relevance was rated 1 out of 5. As a result, the overall impact score was **2**.

Econ-5.3: The overall impact of related and supporting industries in South Africa is considered substantial as South Africa is the dominant producer of platinum globally and therefore has strong upstream supporting industries for platinum jewellery production. The gold industry may be seen as a related industry in South Africa from which knowledge can be leveraged, especially from jewellery hubs that are being developed to stimulate the fabrication of gold jewellery. Both the potential impact and relevance of related and supporting industries were therefore rated 4 out of 5, giving an overall impact score of **7**.

Econ-5.4: The potential impact of rivalry on the feasibility of establishing a platinum jewellery in South Africa is considered substantial. A platinum jewellery industry in South Africa would have to target the export market for its products as the local market is not very large. Therefore, as a new industry in South Africa, the platinum jewellery industry is threatened by new entrants (globally) competing in the same market, substitution of platinum jewellery by other jewellery types (white gold, titanium etc.) and the strong bargaining power of customers. However, the diversity of jewellery that can be manufactured increases the potential for innovative organisations to gain or maintain market share. As such, the potential impact was rated 4 out of 5, with the relevance rated 3 out of 5. The overall impact score was therefore **-6** (rivalry has a negative influence on the feasibility of a new industry).

Econ-6:

To account for uncertainty, the impact scores for all the sub-indicators of which indicator Econ-6 is composed, were varied in the uncertainty analysis (as presented in Section 5.3).

Econ-6.1: The overall potential impact of political factors is considered moderate. The production of jewellery has been identified as a potential industry to be developed in South Africa (although not specifically platinum jewellery) and incentives has been put in place. The production of platinum jewellery may therefore benefit from existing incentive schemes. Both the impact and relevance of political factors was therefore rated 3 out of 5. The overall impact score was therefore **5**.

Econ-6.2: The potential impact of regulatory factors on the feasibility of a platinum jewellery industry in South Africa is considered minimal. The author has no reason to believe that any regulatory factors exist that significantly influences the feasibility of a platinum jewellery industry in South Africa. The overall impact score was therefore **1**.

Econ-6.3: The potential impact of cultural and demographic factors is considered minimal. The author has no reason to believe that any cultural or demographic factors exist that significantly influences the feasibility of a platinum jewellery industry in South Africa. The overall impact score was therefore **1**.

C.1.2 Environmental indicators

Envi-1:

Envi-1.1: The subject organisation from which data to represent the platinum jewellery industry was gathered does not report the mass or volume of material it consumes annually. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-1.2: The subject organisation from which data to represent the platinum jewellery industry was gathered does not report the mass or volume of water it consumes annually. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-1.3: The life cycle impact of the material consumed by the platinum jewellery industry is considered to be minimal as it makes use of fewer raw materials than most other industries (due to the simplicity of jewellery items). As such, the potential impact and the relevance of the life cycle impact of its material consumption is rated 2 out of 5. Therefore the overall impact score is **3**.

Envi-2:

Envi-2.1: The subject organisation reported 410 364 GJ of scope 1 & 2 energy consumption. Assuming that energy consumption can be scaled according to the proportion of total sales contributed by the sale of platinum jewellery, then, making use of the 46% calculated in equation C.4 earlier:

$$\begin{aligned} Total\ energy\ consumption\ (Scope\ 1\ \&\ 2) &= 410\,364\ GJ \times 46\% \\ &= \mathbf{188\ 745\ GJ} \end{aligned} \tag{C.13}$$

To account for the uncertainty introduced by the assumption, the percentage value was varied in the uncertainty analysis (as presented in Section 5.3).

Envi-2.2: The life cycle impact of the energy consumed by the jewellery industry is considered minimal. Jewellery does not use energy after production, nor is energy consumed by end-of-life disposal significant as jewellery can last for an indefinite period. Further, jewellery is a low volume product, therefore emissions from transport is expected to be low. Energy consumption as a result of waste generated during production and packaging of jewellery are considered to be more significant, albeit tough to quantify. Both the impact and relevance was therefore rated 2 out of 5. As a result, the overall impact score was therefore **3**.

Envi-3:

Envi-3.1: The subject organisation reported total greenhouse gas emissions of 46 388 metric tonnes of CO_2 equivalent (scope 1 & 2). Assuming that emissions can be scaled according to the proportion of total sales contributed by the sale of platinum jewellery, then, making use of the 46% calculated in equation C.4 earlier:

$$\begin{aligned} &Total\ greenhouse\ gas\ emissions\ (Scope\ 1\ \&\ 2) \\ &\qquad = 46\,388\ tonnes \times 46\% \\ &\qquad = \mathbf{21\ 336\ metric\ tonnes\ of\ CO_2\ equivalent} \end{aligned} \tag{C.14}$$

To account for the uncertainty introduced by the assumption, the percentage value was varied in the uncertainty analysis (as presented in Section 5.3).

Envi-3.2: The subject organisation from which data to represent the platinum jewellery industry was gathered does not report the its annual scope 3 greenhouse gas emissions. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-3.3: The subject organisation reported no significant emissions of ozone-depleting substances. A value of **zero** was therefore used for this sub-indicator.

Envi-3.4: The subject organisation reported no significant air emissions. A value of **zero** was therefore used for this sub-indicator.

Envi-4:

Envi-4.1: The subject organisation from which data to represent the platinum jewellery industry was gathered does not report the its annual water discharges. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-4.2: The subject organisation from which data to represent the platinum jewellery industry was gathered does not report the its annual waste generation. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-4.3: The overall quality of waste generated by the platinum jewellery industry is considered poor. Wastewater produced during jewellery manufacturing is contaminated with metals and may contain cyanide (State of California Department of Toxic Substances Control, 2002). As such, the potential impact was rated 4 out of 5 and the relevance of the impact 3 out of 5. The overall impact score was therefore **-6** (poor waste quality has a negative influence on the feasibility of a new industry). To account for the uncertainty in this quantification, the impact score value was varied in the uncertainty analysis (as presented in Section 5.3).

Envi-5:

The subject organisation from which data to represent the platinum jewellery industry was gathered does not report this indicator as it is not material according to the organisation's materiality review process. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-6:

The potential supply chain environmental impacts are considered very substantial. The platinum jewellery industry almost always make use of diamonds and other gemstones, and is often accompanied by production of jewellery from other precious metals such as gold and silver. Mining of diamonds, gemstones and precious metals have in the past resulted in many environmental violations, and although regulation of these industries are increasingly stringent, such negative impacts still prevail in some areas. As such, the potential impact was rated 4 out of 5 and the likelihood of these negative impacts was rated 3 out of 5. The overall risk score was therefore **6**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

C.1.3 Social indicators

Soci-1:

Soci-1.1: The subject organisation reported that it employed approximately 12000 employees. Assuming approximately linear distribution of employment according to sales, the employment linked by the sale of platinum jewellery can be estimated by making use of the percentage calculated in equation C.4:

$$\begin{aligned} Total\ employment &= 12000 \times 46\% \\ &= \textbf{5520 employees} \end{aligned} \tag{C.15}$$

To account for the uncertainty introduced by the assumption, the percentage value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-1.2: The impact of employment in the platinum jewellery industry is considered positive as the industry typically employs a semi-skilled to skilled workforce (Hsu *et al.*, 2014). Certificate training programs and degree programs in gemology were established successfully in China and contributed significantly toward the success of its jewellery industry (Hsu *et al.*, 2014). If similar programs can be established in South Africa, the platinum jewellery industry has the potential to generate a substantial amount of employment. As such, the potential employment impact of the jewellery industry is considered substantial. An impact of 4 out of 5 and a relevance of 3 out of 5 is therefore considered appropriate, producing an overall impact score of **6**. To account for the uncertainty in this quantification, the impact score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-2:

The subject organisation reported a recordable incidence rate of 2.21 per 100 full-time equivalent employees for its operations in the U.S.A. (employing approximately 5700 employees). Assuming this incidence rate is representative of all its operations, the total recordable incidents can thus be calculated by using the 12 000 employees reported in Soci-1.1:

$$\begin{aligned} Total\ recordable\ incidents\ for\ all\ operations &= \frac{2.21}{100} \times 12000 \\ &= 265\ incidents\ for\ the\ year \end{aligned} \tag{C.16}$$

Assuming the number of incidents is proportional to the employment, the number of recordable incidents attributable to the production and sale of platinum jewellery can be calculated by scaling the number of incidents consistent with the scaling in Soci-1.1:

$$\begin{aligned} Total\ recordable\ incidents &= 265 \times 46\% \\ &= \mathbf{122\ incidents\ per\ year} \end{aligned} \tag{C.17}$$

To account for the uncertainty introduced by the scaling, the percentage value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-3:

The subject organisation from which data to represent the platinum jewellery industry was gathered does not report the the annual training its employees receive. This indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Soci-4:

Soci-4.1: The potential of negative impacts for labour practices in the supply chain is considered moderate for the platinum jewellery industry. The diamond, gemstone and precious metal mining industries inherently form part of the platinum jewellery supply chain and these operations introduce notable risk for labour abuses in the supply chain as these mining operations are sometimes poorly regulated. Both the potential impact and likelihood are therefore considered 3 out of 5. The overall risk score is therefore **5**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-4.2 through Soci-4.5: The author is unaware of any reason to believe that the risk for these violations are significantly higher in the platinum jewellery industry than in any other industry being considered. These indicators are therefore not considered in the application of the framework presented in this report.

Soci-4.6: The potential for negative human rights impacts in the supply chain is considered substantial for the platinum jewellery industry. The diamond, gemstone and precious metal mining industries inherently form part of the platinum jewellery supply chain and these operations introduce notable risk for human rights violations in the supply chain as these mining operations are sometimes poorly regulated. The impact of such abuses may be very profound and therefore the impact is rated 5 out of 5, while the likelihood for such impacts are considered lower at 3 out of 5. The overall risk score is therefore **7**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-5:

Soci-5.1: The potential impact of the platinum jewellery industry on local communities is considered minimal as it produces limited pollution, requires limited land area and no considerable special infrastructure. It can however contribute as a major employer in local communities and therefore impact such communities significantly by its business decisions. As a result the impact is rate 3 out of 5, while the likelihood of such impacts is considered low (1 out of 5). The resulting overall risk score is therefore **3**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-5.2: The author is unaware of any reason to believe that the risk for corruption is significantly higher in the platinum jewellery industry than in any other industry being considered. This indicator is therefore not considered.

Soci-5.3: The potential for negative impacts on society in the platinum jewellery supply chain is considered substantial in comparison to other platinum-consuming industries. The platinum jewellery industry is inherently linked to the precious metal mining industry and is almost always also linked to diamond and gemstone production. These mining operations are sometimes located in poorly developed and empoverished countries and can therefore, if poorly regulated, have far reaching negative impacts in these regions. International regulatory processes, such as the Kimberley Process Certification Scheme for diamonds, are in place to limit the potential for such impacts, but cannot completely prevent the possibility for negative impacts. As such, the potential impact is rated 5 out of 5, while the likelihood of such impacts is rated 3 out of 5. The overall risk score is therefore **7**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-6:

Soci-6.1: The potential for negative customer health and safety impacts is considered minimal. Platinum jewellery products generally only present a risk for allergies, but are produced to be hypoallergenic. The potential for negative impacts on customer health and safety is therefore very low. Both the impact and likelihood is rated 1 out of 5, giving an overall risk score of **1**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-6.2: The risk for the sale of banned or disputed products is considered significant for the platinum jewellery industry. The diamond, gemstone and precious metal mining industries inherently form part of the platinum jewellery supply chain and these operations introduce substantial risk that illegally produced materials may be used. Generally, the supply of precious metals and gemstones (especially diamonds) are well regulated. The potential impact is therefore considered 5 out of 5, while the likelihood is rated 2 out of 5. The overall risk score is therefore **6**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

C.2 Catalytic converter industry

This section presents the calculations for the catalytic converter industry. Sections C.2.1, C.2.2 and C.2.3 present the calculations for the economic, environmental and social indicators, respectively.

C.2.1 Economic indicators

Econ-1:
The subject organisation's operations are divided into segments, one of which, call it the catalytic converter segment, is relevant to the present investigation. The operating profit is reported on segmented basis and amounted to £236 900 000 for catalytic converter segment for the year period considered. The net earnings are not reported on segmented basis, but the overall operating

profit and net earnings are known, therefore:

$$
\begin{aligned}
Net\,earnings\,as\,a\,percentage\,of\,operating\,profit &= 100(\frac{Net\,earnings}{Operating\,profit}) \\
&= 100(\frac{£427\,300\,000}{£532\,800\,000}) \\
&= \boxed{80.2\%} \qquad \text{(C.18)}
\end{aligned}
$$

Assuming this percentage is similar for all operations, the net earnings generated by the catalytic converter segment only can be estimated based on the operating profit reported for the segment:

$$
\begin{aligned}
Catalytic\,converter\,segment\,net\,earnings &= £236\,900\,000 \times \boxed{80.2\%} \\
&= £189\,993\,800 \\
&= \mathbf{US\$304\,257\,971}
\end{aligned} \qquad \text{(C.19)}
$$

To account for the uncertainty in the use of the percentage given by C.18, the percentage value was varied in the uncertainty analysis (as presented in Section 5.3).

For calculations later on, note that the organisation reports the portion of the total sales of the organisation contributed by the catalytic converter segment is approximately:

$$\boxed{56\%} \qquad \text{(C.20)}$$

Econ-2:

The financial risks posed by climate change is expected to be significant for the organisation. Changes in the understanding of climate change and its causes and, subsequently, it mitigation, may have a significant negative impact on the catalytic converter industry. Further, the development of a new technology (for eg. fuel cells) motivated by increasing climate change may result in a diminishing market for catalytic converters. The risks posed by climate change were therefore rated 5.

The financial opportunities posed by climate change is expected to be substantial for the organisation. The catalytic converter industry is based on climate change and its mitigation, and future climate change therefore only strengthens the market for catalytic converters. The opportunities generated by climate change is therefore rated 8. Therefore:

$$
\begin{aligned}
Risks &= -5 \\
Opportunities &= 8
\end{aligned}
$$

Summing the risks and opportunities to attain an overall score gives

$$Overall = \boxed{\mathbf{3}} \tag{C.21}$$

To account for uncertainty in this quantification, the overall score was varied in the uncertainty analysis, as presented in Section 5.3.

Econ-3:

The potential positive indirect economic impacts of a platinum jewellery industry were considered substantial. To quantify the potential positive impact, the impact was considered high (4 out of 5). Production of catalytic converters is already established in South Africa and links strongly to the automotive industry. The production of catalytic converters can therefore have a very significant widespread impact by job creation for different levels of employees (including in areas of high poverty). The catalytic converters industry can also have an impact on upstream industries, such as the steel industry, and may result in development of new infrastructure or improvement of existing infrastructure (eg. rail, roads, ports for export). The potential high impact can therefore be widespread, therefore the relevance was deemed high (4 out of 5).

The potential negative indirect economic impacts of a platinum jewellery industry were considered minimal. Further development of the catalytic converter industry may strain existing infrastructure and therefore have a negative economic impact in some areas. However, the likelihood of such negative impacts being substantial is low. The potential impact and its relevance were therefore given 2 out of 5. Therefore:

$$Positive\ impacts = 7$$
$$Negative\ impacts = -3$$

Summing the potential positive and negative impact scores to attain an overall score gives

$$Overall = \boxed{\mathbf{4}} \tag{C.22}$$

To account for uncertainty in this quantification, the overall score was varied in the uncertainty analysis, as presented in Section 5.3.

Econ-4:

Dewar (2012) reports that: "The South African catalytic converter industry is a complex vertically-integrated supply chain with a local content in excess of 85 per cent, substantially more than any other exported automotive component." Therefore, **85%** was used as estimate for this indicator. To account for uncertainty in this estimate, the overall score was varied in the uncertainty analysis, as presented in Section 5.3.

Econ-5:

To account for uncertainty, the impact scores for all the sub-indicators of which indicator Econ-5 is composed, were varied in the uncertainty analysis (as presented in Section 5.3).

Econ-5.1: The overall impact of factor conditions in South Africa that enhances the feasibility of the catalytic converter industry is deemed moderate. South Africa has basic factors (availability of labour, platinum, steel) enhancing the feasibility of a catalytic converter industry, but has no significant specialised factors that enhances the feasibility of such an industry. Therefore both the significance (impact) and relevance of these factors were rated 3 out of 5. As a result, the allocated overall impact score was **5**.

Econ-5.2: The overall impact of demand conditions in South Africa that enhances the feasibility of the catalytic converter industry is deemed moderate. Local automotive manufacturers produce vehicles of international standard and serves as both demand for catalytic converters as well as to provide stringent requirements for local catalytic converter manufacturers. Thus, the impact and relevance was rated 3 out of 5. As a result, the overall impact score was **5**.

Econ-5.3: The overall impact of related and supporting industries in South Africa is considered substantial. Local automotive manufacturers serve as a strong downstream supporting industry for the catalytic converter industry, while the steel and platinum production industries serve as strong upstream supporting industries. No significant related industries exist in South Africa. Both the potential impact and relevance of related and supporting industries were therefore rated 4 out of 5, giving an overall impact score of **7**.

Econ-5.4: The potential impact of rivalry on the feasibility of the catalytic converter industy in South Africa is considered moderate. The catalytic converter industry is fiercely competitive internationally, but South Africa already has a significant footprint in this industry (between 10 and 15% global market share (Dewar, 2012; South African Chamber of Mines, 2015)) and the negative impacts of rivalry is therefore offset by the improvement in global competitiveness that result from rivalry. As such, the overall impact score was estimated to be **-3** (rivalry still has a negative influence on the feasibility of the industry, although it also has some positive influence as well).

Econ-6:

To account for uncertainty, the impact scores for all the sub-indicators of which indicator Econ-6 is composed, were varied in the uncertainty analysis (as presented in Section 5.3).

Econ-6.1: The overall potential impact of political factors is considered substantial. As one of the few industries in which South Africa has a significant international market share, the production of catalytic converters is supported by several incentive schemes aimed at the automotive manufacturing and automotive component industries (for example the Automotive Production and Development Programme, APDP). Both the impact and relevance of political factors was therefore rated 4 out of 5. The overall impact score was therefore **7**.

Econ-6.2: The potential impact of regulatory factors on the feasibility of the catalytic converter industry in South Africa is considered minimal. The author has no reason to believe that any regulatory factors exist that significantly influences the feasibility of the catalytic converter industry in South Africa. The overall impact score was therefore **1**.

Econ-6.3: The potential impact of cultural and demographic factors is considered minimal. The author has no reason to believe that any cultural or demographic factors exist that significantly influences the feasibility of the catalytic converter industry in South Africa. The overall impact score was therefore **1**.

C.2.2 Environmental indicators

Envi-1:

Envi-1.1: The subject organisation from which data was gathered to represent the catalytic converter industry does not report the mass or volume of material it consumes annually. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-1.2: Although the subject organisation from which data was gathered to represent the catalytic converter industry does report this indicator, the organisation used to represent the platinum jewellery industry does not report this indicator and therefore this sub-indicator could not be used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-1.3: The life cycle impact of the material consumed by the catalytic converter industry is considered to be significant as the industry makes use of several raw materials, including steel and ceramics. As such, the potential impact of its material consumption is rated 4 out of 5 and the relevance of the life cycle impact of its material consumption was rated 3 out of 5. Therefore the overall impact score was **6**.

Envi-2:

Envi-2.1: The subject organisation reported 5 360 000 GJ of scope 1 & 2 energy consumption. Assuming that energy consumption can be scaled according to the proportion of the total sales of the organisation contributed by the catalytic converter segment (56%, as reported in equation C.20), then:

$$\begin{aligned} Total\ energy\ consumption\ (Scope\ 1\ \&\ 2) &= 5\,360\,000\ GJ \times 56\% \\ &= \mathbf{3\,001\,600\ GJ} \end{aligned} \tag{C.23}$$

To account for the uncertainty introduced by the assumption, the percentage value was varied in the uncertainty analysis (as presented in Section 5.3).

Envi-2.2: The life cycle impact of the energy consumed by the catalytic converter industry is considered significant. Although catalytic converters does not use energy during operation, the energy required for transportation of raw materials for production of catalytic converters as well as the energy required for transportation of the product is significant. The end-of-life treatment (perhaps recycling) of catalytic converters further contribute significantly to the life cycle impact of its energy consumption. The potential impact was therefore rated 4 out of 5 and the relevance was rated 3 out of 5. As a result, the overall impact score was **6**.

Envi-3:

Envi-3.1: The subject organisation reported total greenhouse gas emissions of 469 000 metric tonnes of CO_2 equivalent (scope 1 & 2). Assuming that emissions can be scaled according to the proportion of total sales contributed by the sale of catalytic converters, then, making use of the 56% presented in equation C.20 earlier:

$$\begin{aligned} &Total\ greenhouse\ gas\ emissions\ (Scope\ 1\ \&\ 2) \\ &\quad = 469\,000\ tonnes \times 56\% \\ &\quad = \mathbf{262\,640\ metric\ tonnes\ of\ CO_2\ equivalent} \end{aligned} \tag{C.24}$$

To account for the uncertainty introduced by the assumption, the percentage value was varied in the uncertainty analysis (as presented in Section 5.3).

Envi-3.2: Although the subject organisation from which data was gathered to represent the catalytic converter industry partially reports this indicator, the organisation used to represent the platinum jewellery industry does not report this indicator and therefore this sub-indicator could not be used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-3.3: The subject organisation reported no significant emissions of ozone-depleting substances. A value of **zero** was therefore used for this sub-indicator.

Envi-3.4: The subject organisation reported the following emissions:

$$\begin{aligned} Total\ acid\ gas\ emissions &= 394\ tonnes\ of\ SO_2\ equivalent \\ Total\ NO_x\ emissions &= 497\ tonnes \\ Total\ SO_2\ emissions &= 46.1\ tonnes \\ Total\ VOC\ emissions &= 153.9\ tonnes \end{aligned}$$

Therefore:

$$Total\ gaseous\ emissions = 1091\ tonnes$$

Assuming that emissions can be scaled according to the proportion of total sales contributed by the sale of catalytic converters, then, making use of the 56% presented in equation C.20 earlier:

$$\begin{aligned} &Total\ gaseous\ emissions\ for\ catalytic\ converter\ segment \\ &\qquad = 1091\ tonnes \times 56\% \\ &\qquad = \mathbf{611\ tonnes} \end{aligned} \tag{C.25}$$

Envi-4:

Envi-4.1: Although the subject organisation from which data was gathered to represent the catalytic converter industry does report this indicator, the organisation used to represent the platinum jewellery industry does not report this indicator and therefore this sub-indicator could not be used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-4.2: Although the subject organisation from which data was gathered to represent the catalytic converter industry does report this indicator, the organisation used to represent the platinum jewellery industry does not report this indicator and therefore this sub-indicator could not be used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-4.3: The overall quality of waste generated by the catalytic converter industry is considered fairly good. The industry does not produce hazardous waste and catalytic converter companies globally are making efforts to produce no landfill waste. As such, both the potential impact and the relevance of the impact was rated 2 out of 5. The overall impact score was therefore **-3** (waste quality is fairly high but still has a negative influence on the feasibility of a new industry). To account for the uncertainty in this quantification, the impact score value was varied in the uncertainty analysis (as presented in Section 5.3).

Envi-5:

The subject organisation from which data to represent the catalytic converter industry was gathered does not report this indicator. This sub-indicator was therefore not used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Envi-6:

The potential supply chain environmental impacts are considered moderate. Environmental impacts associated with manufacture of components (such as the stainless steel casing and ceramic substrate), as well as the end of life disposal of catalytic converters may be substantial. However, such impacts are generally regulated stringently and therefore a low likelihood score is assigned. As such, the potential impact was rated 4 out of 5 and the likelihood of these negative impacts was rated 2 out of 5. The overall risk score was therefore **5**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

C.2.3 Social indicators

Soci-1:

Soci-1.1: The subject organisation reported that it employed 12148 employees in the subject year. **4683** of those employees were reported to be employed in the catalytic converter segment.

Soci-1.2: The impact of employment in the catalytic converter industry is considered positive. The industry depends heavily on continuous improvement of technology and therefore generally invests in research and development and highly skilled experts. The production processes further also require a range of semi-skilled and skilled employees. As such, the potential employment impact of the jewellery industry is considered substantial. An impact of 4 out of 5 and a relevance of 4 out of 5 is therefore considered appropriate, producing an overall impact score of **7**. To account for the uncertainty in this quantification, the impact score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-2:

The subject organisation reported a total recordable illness and injury rate of 1.14 per 100 full-time equivalent employees and 1.2 new occupational illness cases per 1000 employees for its operations. Assuming this incidence rate is representative of all its operations, the total recordable incidents can thus be calculated by using the 12 148 employees reported in Soci-1.1:

$$\begin{aligned} Total\ recordable\ illness\ and\ injury\ rate &= \frac{1.14}{100} \times 12148 \\ &= 138.5\ incidents\ for\ the\ year \end{aligned}$$

Similarly,

$$\begin{aligned} Total\ occupational\ illness\ cases &= \frac{1.2}{1000} \times 12148 \\ &= 14.6\ incidents\ for\ the\ year \end{aligned}$$

Therefore,

$$\begin{aligned} &Total\ recordable\ illness,\ injury\ \&\ occupational\ illness\ cases \\ &= 138.5 + 14.6 \\ &= 153.1\ cases\ for\ the\ year \end{aligned}$$

Assuming these cases are linearly distributed over all operations, the approximate number of cases attributable to the catalytic converter segment can be calculated by to using the number of employees employed by that segment:

$$\begin{aligned} &Total\ recordable\ illness,\ injury\ \&\ occupational\ illness\ cases \\ for\ the\ catalytic\ converter\ segment &= 153.1 \times \frac{4683}{12148} \\ &= \boxed{\textbf{59.0 cases for the year}} \end{aligned} \tag{C.26}$$

To account for the uncertainty, the final value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-3:

Although the subject organisation from which data was gathered to represent the catalytic converter industry does report this indicator, the organisation used to represent the platinum jewellery industry does not report this indicator and therefore this sub-indicator could not be used in the application of the framework. This was taken into account in the uncertainty analysis (as presented in Section 5.3).

Soci-4:

Soci-4.1: The potential of negative impacts for labour practices in the supply chain is considered minor for the catalytic converter industry. The author is not aware of any reason to believe that negative impacts due to poor labor practices may be prevalent in the catalytic converter supply chain. Due to the fairly large and complex nature of the supply chain an impact score of 3 is awarded, although the likelihood of such impacts is deemed to be low and is therefore rated 1 out of 5. The overall risk score is therefore **3**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-4.2 through Soci-4.5: The author is unaware of any reason to believe that the risk for these violations are significantly higher in the catalytic converter industry than in any other industry being considered. These indicators are therefore not considered in the application of the framework presented in this report.

Soci-4.6: The potential for negative human rights impacts in the supply chain is considered minor for the catalytic converter industry. The author is not aware of any reason to believe that human rights violations may be prevalent in the catalytic converter supply chain. Due to the fairly large and complex nature of the supply chain an impact score of 4 is awarded, although the likelihood of such impacts is deemed to be low and is therefore rated 1 out of 5. The overall risk score is therefore **3**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-5:

Soci-5.1: The potential impact of the catalytic converter industry on local communities is considered significant. The industry consumes a substantial amount of water and produces several waste and emissions streams. The potential impact of such an industry on local communities can therefore be substantial. As a result the impact is rated 4 out of 5, while the likelihood of such impacts is considered to be lower (3 out of 5). The resulting overall risk score is therefore **6**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-5.2: The author is unaware of any reason to believe that the risk for corruption is significantly higher in the catalytic converter industry than in any other industry being considered. This indicator is therefore not considered.

Soci-5.3: The potential for negative impacts on society in the catalytic converter supply chain is considered moderate in comparison to other platinum-consuming industries. The catalytic converter industry makes use of several raw materials (steel, precious metals, ceramics etc.). The production of these materials may have some substantial economic, environmental and social impacts on the communities where the materials are produced. Such negative impacts are, however, well regulated in general. As such, the potential impact is rated 4 out of 5, while the likelihood of such impacts is rated 2 out of 5. The overall risk score is therefore **5**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-6:

Soci-6.1: The potential for negative customer health and safety impacts is considered moderate. Catalytic converters are responsible for the conversion of unwanted exhaust emissions to more acceptable forms. Failure of catalytic converters may result in large scale air pollution, with potentially severe impacts. However, the likelihood for such an event is deemed to be low. The end of life disposal of catalytic converters also presents a risk for pollution and emission of harmful chemicals. The potential impact is therefore rated 4 out of 5, while the likelihood is rated 2 out of 5, giving an overall risk score of **5**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

Soci-6.2: The risk for the sale of banned or disputed products is considered moderate for the catalytic converter industry. Although there is a continuous debate on the environmental impacts related to exhaust emissions, it is generally accepted that catalytic converters serve the good, and much needed, purpose of converting the emissions a less harmful state. However, catalytic converters may be seen as an interim technology - treating a problem that should be prevented completely by adoption of less polluting automotive technologies. The potential impact is therefore considered 4 out of 5, while the likelihood is rated 1 out of 5. The overall risk score is therefore **4**. To account for the uncertainty in this quantification, the risk score value was varied in the uncertainty analysis (as presented in Section 5.3).

C.3 Scaling

This section outlines the calculations done in the scaling of the data as described in Section 5.2.

C.3.1 Platinum jewellery industry

Johnson Matthey (2015) reports that the gross global use of platinum by the jewellery industry amounted to 2 894 000 troy oz (90 013 529 grams) in 2014 (the year of all reported data and calculations). Using the values calculated for net sales of platinum statement, fine and solitaire jewellery and net sales of platinum engagement jewellery and wedding bands as given by equations C.1 and C.2, and the values given by numbers 7 and 8 in Table C.2, the estimated platinum consumption of the organisation can be calculated:

Assuming each jewellery piece contains 6 grams of platinum (see discussion of this assumption in Section 5.2):

$$\begin{aligned} &Estimated\ amount\ of\ platinum\ used\ in\ statement,\ fine\ and\ solitaire\\ &jewellery = 6\ g \times \frac{US\$809\ 234\ 850}{US\$5\ 400}\\ &= 899\ 150\ g \end{aligned} \tag{C.27}$$

$$\begin{aligned} &Estimated\ amount\ of\ platinum\ used\ in\ engagement\ jewellery\ and\\ &wedding\ bands = 6\ g \times \frac{US\$1\ 145\ 492\ 920}{US\$3\ 600}\\ &= 1\ 909\ 155\ g \end{aligned} \tag{C.28}$$

Assuming 5% loss of platinum metal mass during fabrication (varied in uncertainty analysis):

$$\begin{aligned} &Total\ mass\ of\ platinum\ consumed\ by\ organisation\\ &= (899\ 150 + 1\ 909\ 155) \times (1 + \frac{5\%}{100})\\ &= 2\ 948\ 720\ g \end{aligned} \tag{C.29}$$

Therefore,

$$\begin{aligned}&Total\ mass\ of\ platinum\ consumed\ by\ organisation\ as\ a\ percentage\ of\ gross\\ &global\ consumption = 100 \times \frac{2\,948\,720}{90\,013\,529}\\ &= 3.28\% \qquad (C.30)\end{aligned}$$

C.3.2 Catalytic converter industry

The Automotive Industry Export Council (2015) reports the total annual exports of catalytic converters from South Africa in 2014 to have amounted to R19 493 million (about £1 092 875 045). The organisation reported £3 577 700 000 of revenue from the catalytic converter segment. This value had to be adjusted to include only sales revenue (excluding revenue from interest, sales of assets etc.). This adjustment was done by assuming the sales revenue as a percentage of total revenue generated by the organisation is approximately constant across all its operations. Therefore:

$$\begin{aligned}Sales\ revenue\ as\ a\ percentage\ of\ total\ revenue &= 100 \times \frac{\pounds 9846.8\, mil}{\pounds 10059.7\, mil}\\ &= 97.88\% \qquad (C.31)\end{aligned}$$

This value was varied in the uncertainty analysis. Then it follows that,

$$\begin{aligned}Sales\ revenue\ for\ catalytic\ converter\ segment &= 97.88\% \times \pounds 3\,577\,700\,000\\ &= \pounds 3\,501\,852\,760 \qquad (C.32)\end{aligned}$$

Finally, assuming that almost all revenue generated by the catalytic converter industry in South Africa is in the form of exports:

$$\begin{aligned}&South\ African\ catalytic\ converter\ industry\ revenue\ from\ exports\ as\ a\\ &percentage\ of\ organisation\ revenue\ from\ sales\ of\ catalytic\ converters\\ &= 100 \times \frac{\pounds 1\,092\,875\,045}{\pounds 3\,501\,852\,760}\\ &= 31.2\% \qquad (C.33)\end{aligned}$$

Appendix D

Uncertainty and sensitivity analysis

This appendix presents a summary of the inputs that were varied in the uncertainty analysis, along with the specifications of the probability distribution functions used and the main simulation results in Table D.1. The sensitivity of the framework outputs to the various inputs are provided in Table D.2.

Table D.1: Summary of inputs varied in the uncertainty analysis

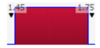
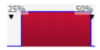
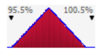
			Distribution		Simulation			
Name	**Eq. no.**	**Value**	**Min**	**Max**	**Min**	**Mean**	**Max**	**Graph**
Uniform probability distribution functions:								
Exchange rate: USD per GBP		1.60141	1.47628	1.72654	1.47628	1.60141	1.72653	
Exchange rate: GBP per ZAR		0.05607	0.05473	0.05740	0.05473	0.05607	0.05740	
Avg. platinum price Feb. 2014 through Jan. 2015 (USD/oz, Johnson Matthey (2016))		1356.21	1190.63	1521.79	1190.65	1356.21	1521.79	
South African potential market share of global platinum jewellery industry		5%	3%	7%	3%	5%	7%	
Adjusted net sales as a percentage of total reported net sales / Jewellery industry	C.4	46%	36%	56%	36%	46%	56%	
Catalytic converter segment sales as a percentage of total sales	C.20	56%	46%	66%	46%	56%	66%	
Employees in catalytic converter segment as a percentage of total employees		39%	29%	49%	29.0%	39.0%	49.0%	
Triangular probability distribution functions:								
Sales revenue as a percentage of total revenue / Catalytic converter industry	C.31	97.88%	95.76%	100%	95.77%	97.88%	99.98%	

Table D.1: Summary of inputs varied in the uncertainty analysis (continued)

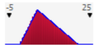
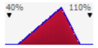
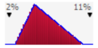
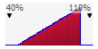
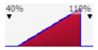
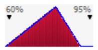
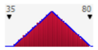
			Distribution		Simulation			
Name	**Eq. no.**	**Value**	**Min**	**Max**	**Min**	**Mean**	**Max**	**Graph**
Average mass of platinum per item / Jewellery industry		6	0.00	20.00	0.10	8.67	19.84	
Econ-4 / Catalytic converter industry		85.00%	50.00%	100%	50.00%	78.00%	100%	
Metal loss during fabrication / Jewellery industry		5.0%	3.0%	10.0%	3.0%	6.0%	10.0%	
Net profit as a percentage of operating profit / Catalytic converter industry		80.2%	60.2%	90.2%	60.3%	76.9%	90.0%	
Percentage of cost of sales sourced locally / Jewellery industry	C.12	100.00%	50.00%	100.00%	50.5%	83.3%	100.0%	
Percentage of selling, general and administrative cost sourced locally / Jewellery industry	C.12	70.00%	45.00%	95.00%	45.1%	70.00%	94.8%	
Soci-2 / Catalytic converter industry		59	39	79	39.1	59	78.9	
Discrete uniform probability distribution functions:								
Econ-2 / Jewellery industry	C.6	0	-1	1	-1	0	1	
Econ-2 / Catalytic converter industry	C.21	3	2	4	2	3	4	
Econ-3 / Jewellery industry	C.7	2	1	3	1	2	3	
Econ-3 / Catalytic converter industry	C.22	4	3	5	3	4	5	
Econ-5.1 / Jewellery industry		5	4	6	4	5	6	

Table D.1: Summary of inputs varied in the uncertainty analysis (continued)

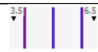
			Distribution		Simulation			
Name	**Eq. no.**	**Value**	**Min**	**Max**	**Min**	**Mean**	**Max**	**Graph**
Econ-5.1 / Catalytic converter industry		5	4	6	4	5	6	
Econ-5.2 / Jewellery industry		2	1	3	1	2	3	
Econ-5.2 / Catalytic converter industry		5	4	6	4	5	6	
Econ-5.3 / Jewellery industry		7	6	8	6	7	8	
Econ-5.3 / Catalytic converter industry		7	6	8	6	7	8	
Econ-5.4 / Jewellery industry		-6	-7	-5	-7	-6	-5	
Econ-5.4 / Catalytic converter industry		-3	-4	-2	-4	-3	-2	
Econ-6.1 / Jewellery industry		5	4	6	4	5	6	
Econ-6.1 / Catalytic converter industry		7	6	8	6	7	8	
Econ-6.2 / Jewellery industry		1	0	2	0	1	2	
Econ-6.2 / Catalytic converter industry		1	0	2	0	1	2	
Econ-6.3 / Jewellery industry		1	0	2	0	1	2	
Econ-6.3 / Catalytic converter industry		1	0	2	0	1	2	
Envi-1.1 / Jewellery industry		$\frac{1}{6}$	0	$\frac{1}{3}$	0	$\frac{1}{6}$	$\frac{1}{3}$	
Envi-1.2 / Jewellery industry		$\frac{1}{6}$	0	$\frac{1}{3}$	0	$\frac{1}{6}$	$\frac{1}{3}$	

Table D.1: Summary of inputs varied in the uncertainty analysis (continued)

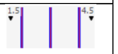
			Distribution		**Simulation**			
Name	**Eq. no.**	**Value**	**Min**	**Max**	**Min**	**Mean**	**Max**	**Graph**
Envi-1.3 / Jewellery industry		3	2	4	2	3	4	
Envi-1.3 / Catalytic converter industry		6	5	7	5	6	7	
Envi-2.2 / Jewellery industry		3	2	4	2	3	4	
Envi-2.2 / Catalytic converter industry		6	5	7	5	6	7	
Envi-3.2 / Jewellery industry		$\frac{1}{8}$	0	$\frac{1}{4}$	0	$\frac{1}{8}$	$\frac{1}{4}$	
Envi-4.1 / Jewellery industry		$\frac{1}{6}$	0	$\frac{1}{3}$	0	$\frac{1}{6}$	$\frac{1}{3}$	
Envi-4.2 / Jewellery industry		$\frac{1}{6}$	0	$\frac{1}{3}$	0	$\frac{1}{6}$	$\frac{1}{3}$	
Envi-4.3 / Jewellery industry		-6	-7	-5	-7	-6	-5	
Envi-4.3 / Catalytic converter industry		-3	-4	-2	-4	-3	-2	
Envi-5 / Jewellery industry		$\frac{1}{12}$	0	$\frac{1}{6}$	0	$\frac{1}{12}$	$\frac{1}{6}$	
Envi-6 / Jewellery industry		6	5	7	5	6	7	
Envi-6 / Catalytic converter industry		5	4	6	4	5	6	
Soci-1.2 / Jewellery industry		6	5	7	5	6	7	
Soci-1.2 / Catalytic converter industry		7	6	8	6	7	8	
Soci-3 / Catalytic converter industry		$\frac{1}{12}$	0	$\frac{1}{6}$	0	$\frac{1}{12}$	$\frac{1}{6}$	

Table D.1: Summary of inputs varied in the uncertainty analysis (continued)

			Distribution		Simulation			
Name	**Eq. no.**	**Value**	**Min**	**Max**	**Min**	**Mean**	**Max**	**Graph**
Soci-4.1 / Jewellery industry		5	4	6	4	5	6	
Soci-4.1 / Catalytic converter industry		3	2	4	2	3	4	
Soci-4.6 / Jewellery industry		7	6	8	6	7	8	
Soci-4.6 / Catalytic converter industry		3	2	4	2	3	4	
Soci-5.1 / Jewellery industry		3	2	4	2	3	4	
Soci-5.1 / Catalytic converter industry		6	5	7	5	6	7	
Soci-5.3 / Jewellery industry		7	6	8	6	7	8	
Soci-5.3 / Catalytic converter industry		5	4	6	4	5	6	
Soci-6.1 / Jewellery industry		1	0	2	0	1	2	
Soci-6.1 / Catalytic converter industry		5	4	6	4	5	6	
Soci-6.2 / Jewellery industry		6	5	7	5	6	7	
Soci-6.2 / Catalytic converter industry		4	3	5	3	4	5	

Table D.2: Sensitivity of the framework outputs to variation in the input values

Name	**Range of mean**	**Percentage variation**
Economic index		
Baseline (mean) index value	**0.2966**	
Econ-4 / Catalytic converter industry	0.1588	54%
Percentage of cost of sales sourced locally / Jewellery industry	0.0862	29%
Percentage of selling, general and administrative cost sourced locally / Jewellery industry	0.0838	28%
Econ-6.2 / Catalytic converter industry	0.0574	19%
Econ-6.2 / Jewellery industry	0.0561	19%
Econ-6.3 / Jewellery industry	0.0556	19%
Econ-6.3 / Catalytic converter industry	0.0517	17%
Average mass of platinum per item / Jewellery industry	0.0362	12%
Econ-3 / Jewellery industry	0.0309	10%
Econ-3 / Catalytic converter industry	0.0290	10%
Econ-5.1 / Catalytic converter industry	0.0248	8%
South African potential market share of global platinum jewellery industry	0.0233	8%
Econ-5.1 / Jewellery industry	0.0207	7%
Adjusted net sales as a percentage of total reported net sales / Jewellery industry	0.0203	7%
Econ-5.3 / Catalytic converter industry	0.0186	6%
Econ-6.1 / Catalytic converter industry	0.0180	6%
Econ-5.3 / Jewellery industry	0.0160	5%
Econ-6.1 / Jewellery industry	0.0149	5%
Net profit as a percentage of operating profit / Catalytic converter industry	0.0148	5%
Exchange rate: USD per GBP	0.0147	5%
Econ-2 / Catalytic converter industry	0.0135	5%
Econ-5.4 / Jewellery industry	0.0131	4%
Metal loss during fabrication / Jewellery industry	0.0117	4%

Table D.2: Sensitivity of the framework outputs to variation in the input values (continued)

Name	**Range of mean**	**Percentage variation**
Econ-5.4 / Catalytic converter industry	0.0104	3%
Econ-5.2 / Catalytic converter industry	0.0101	3%
Exchange rate: GBP per ZAR	0.0095	3%
Econ-5.2 / Jewellery industry	0.0091	3%
Econ-2 / Jewellery industry	0.0090	3%
Sales revenue as a percentage of total revenue / Catalytic converter industry	0.0077	3%
Environmental index		
Baseline (mean) index value	**0.6121**	
Envi-5 / Jewellery industry	0.1656	27%
Average mass of platinum per item / Jewellery industry	0.0916	15%
Envi-6 / Catalytic converter industry	0.0853	14%
Envi-1.1 / Jewellery industry	0.0841	14%
Envi-6 / Jewellery industry	0.0826	13%
Envi-4.1 / Jewellery industry	0.0825	13%
Envi-4.2 / Jewellery industry	0.0821	13%
Envi-1.2 / Jewellery industry	0.0816	13%
South African potential market share of global platinum jewellery industry	0.0183	3%
Adjusted net sales as a percentage of total reported net sales / Jewellery industry	0.0168	3%
Envi-2.2 / Jewellery industry	0.0159	3%
Econ-1 / Catalytic converter industry	0.0148	2%
Exchange rate: GBP per ZAR	0.0138	2%
Sales revenue as a percentage of total revenue / Catalytic converter industry	0.0138	2%
Metal loss during fabrication / Jewellery industry	0.0103	2%
Envi-4.3 / Catalytic converter industry	0.0078	1%
Envi-1.3 / Jewellery industry	0.0068	1%
Envi-4.3 / Jewellery industry	0.0067	1%
Envi-2.2 / Catalytic converter industry	0.0042	1%

Table D.2: Sensitivity of the framework outputs to variation in the input values (continued)

Name	**Range of mean**	**Percentage variation**
Envi-3.2 / Jewellery industry	0.0039	1%
Envi-1.3 / Catalytic converter industry	0.0032	1%
Social index		
Baseline (mean) index value	**0.3798**	
Soci-3 / Jewellery industry	0.1647	43%
Soci-1.2 / Jewellery industry	0.0585	15%
Soci-1.2 / Catalytic converter industry	0.0520	14%
Soci-6.2 / Catalytic converter industry	0.0300	8%
Soci-5.3 / Catalytic converter industry	0.0295	8%
Soci-6.2 / Jewellery industry	0.0278	7%
Soci-5.3 / Jewellery industry	0.0276	7%
Soci-4.1 / Jewellery industry	0.0114	3%
South African potential market share of global platinum jewellery industry	0.0103	3%
Soci-5.1 / Catalytic converter industry	0.0088	2%
Adjusted net sales as a percentage of total reported net sales / Jewellery industry	0.0086	2%
Sales revenue as a percentage of total revenue / Catalytic converter industry	0.0079	2%
Exchange rate: GBP per ZAR	0.0078	2%
Soci-2 / Catalytic converter industry	0.0068	2%
Metal loss during fabrication / Jewellery industry	0.0063	2%
Average mass of platinum per item / Jewellery industry	0.0061	2%
Soci-4.6 / Jewellery industry	0.0058	2%
Soci-5.1 / Jewellery industry	0.0049	1%
Soci-6.1 / Jewellery industry	0.0039	1%
Soci-4.6 / Catalytic converter industry	0.0038	1%
Soci-6.1 / Catalytic converter industry	0.0035	1%
Soci-4.1 / Catalytic converter industry	0.0033	1%

Appendix E

Results

This appendix presents a summary of the results of comparing the jewellery industry and the catalytic converter industry by using the framework.

Table E.1 presents a summary of the results of comparing the industries in terms of the static indicator values calculated in Appendix C.

Table E.2 presents the frequency distribution data for the results of each index when the input variables are varied in the uncertainty analysis (as described in Section 5.3 in Chapter 5 and Appendix D).

Table E.1: Results of comparing the jewellery industry and the catalytic converter industry using static values

ID	Name	Units	Weight	Impact	Jewellery industry	Cat. conv. industry	Jewellery industry score	Cat. conv. industry score
Economic indicators							3/12	9/12
Econ-1	**Economic value**	**Expected earnings**	**1/6**	**1**	**US$ 339 944 523**	**US$ 94 954 290**	**1/6**	**0**
Econ-2	**Climate change risks**	**Risk score**	**1/6**	**1**	**0**	**3**	**0**	**1/6**
Econ-3	**Indirect economic impacts**	**Impact score**	**1/6**	**1**	**2**	**4**	**0**	**1/6**
Econ-4	**Local suppliers**	**Percentage of operating cost**	**1/6**	**1**	**85%**	**85%**	**1/12**	**1/12**
Econ-5	**Competitiveness**	**Impact score**	**1/6**				**0**	**1/6**
Econ-5.1	Factor conditions	Impact score	1/4	1	5	5	1/8	1/8
Econ-5.2	Demand conditions	Impact score	1/4	1	2	5	0	1/4
Econ-5.3	Related & supporting industries	Impact score	1/4	1	7	7	1/8	1/8
Econ-5.4	Rivalry	Impact score	1/4	1	-6	-3	0	1/4
Econ-6	**Socio-economic factors**	**Impact score**	**1/6**				**0**	**1/6**
Econ-6.1	Political factors	Impact score	1/3	1	5	7	0	1/3
Econ-6.2	Regulatory factors	Impact score	1/3	1	1	1	1/6	1/6
Econ-6.3	Cultural & demographic factors	Impact score	1/3	1	1	1	1/6	1/6

Table E.1: Results of comparing the jewellery industry and the catalytic converter industry by making use of the framework (continued)

ID	Name	Units	Weight	Impact	Jewellery industry	Cat. conv. industry	Jewellery industry score	Cat. conv. industry score
Environmental indicators							**7/12**	**5/12**
Envi-1	**Materials consumption**	**Mass & impact of consumption**	**1/6**				**1/6**	**0**
Envi-1.1	Materials by weight	Mass of material	1/3	-1	0	0	1/6	1/6
Envi-1.2	Water withdrawal	Mass of water	1/3	-1	0	0	1/6	1/6
Envi-1.3	Life cycle impact of material consumption	Impact score	1/3	-1	3	6	1/3	0
Envi-2	**Energy consumption**	**Gigajoules & impact of consumption**	**1/6**				**1/6**	**0**
Envi-2.1	Energy consumption (Scope 1 + 2)	Gigajoules	1/3	-1	288119	936754	1/3	0
Envi-2.2	Life cycle impact of energy consumption	Impact score	1/3	-1	3	6	1/3	0
Envi-3	**Total gaseous emissions**	**Mass of gaseous emissions**	**1/6**				**1/6**	**0**
Envi-3.1	GHG emissions (Scope 1)	Mass of CO2 equivalent	1/4	-1	32569	81966	1/4	0
Envi-3.2	GHG emissions (Scope 3)	Mass of CO2 equivalent	1/4	-1	0	0	1/8	1/8

Table E.1: Results of comparing the jewellery industry and the catalytic converter industry by making use of the framework (continued)

ID	Name	Units	Weight	Impact	Jewellery industry	Cat. conv. industry	Jewellery industry score	Cat. conv. industry score
Envi-3.3	Ozone-depleting substances (ODS)	Mass of CFC-11 equivalent	1/4	-1	0	0	1/8	1/8
Envi-3.4	NOx, SOx and other emissions	Mass of noxious gas emissions	1/4	-1	0	191	1/4	0
Envi-4	**Total waste discharge**	**Mass & overall quality of waste**	**1/6**				**0**	**1/6**
Envi-4.1	Water discharge	Mass of water discharge	1/3	-1	0	0	1/6	1/6
Envi-4.2	Waste by type and disposal method	Mass of waste generated	1/3	-1	0	0	1/6	1/6
Envi-4.3	Overall quality of waste	Impact score	1/3	1	-6	-3	0	1/3
Envi-5	**Products and packaging materials reclaimed**	**Percentage reclaimed**	**1/6**	**1**	0	0	**1/12**	**1/12**
Envi-6	**Supply chain environmental impacts**	**Risk score**	**1/6**	**-1**	6	5	**0**	**1/6**

Table E.1: Results of comparing the jewellery industry and the catalytic converter industry by making use of the framework (continued)

ID	**Name**	**Units**	**Weight**	**Impact**	**Jewellery industry**	**Cat. conv. industry**	**Jewellery industry score**	**Cat. conv. industry score**
Social indicators							**4/12**	**8/12**
Soci-1	**Employment**	**Number of employees & impact of employment**	**1/6**				**1/12**	**1/12**
Soci-1.1	Number of new employee hires	Number of employees	1/2	1	8425	1461	1/2	0
Soci-1.2	Impact of employment	Impact score	1/2	1	6	7	0	1/2
Soci-2	**Health & safety risk**	**Total rate of injury and occupational disease (occurrences/time)**	**1/6**	**-1**	**186**	**18**	**0**	**1/6**
Soci-3	**Average hours of training for employees**	**Average hours of training per employee per year**	**1/6**	**1**	**0.0**	**0.0**	**1/12**	**1/12**
Soci-4	**Human rights in whole supply chain**	**Risk score**	**1/6**				**0**	**1/6**
Soci-4.1	Negative impacts for labor practices in the supply chain	Risk score	1/6	-1	5	3	0	1/6
Soci-4.2	Incidents of discrimination	Risk score	1/6	-1	0	0	1/12	1/12

Table E.1: Results of comparing the jewellery industry and the catalytic converter industry by making use of the framework (continued)

ID	**Name**	**Units**	**Weight**	**Impact**	**Jewellery industry**	**Cat. conv. industry**	**Jewellery industry score**	**Cat. conv. industry score**
Soci-4.3	Significant risk of freedom of association in operations and suppliers	Risk score	1/6	-1	0	0	1/12	1/12
Soci-4.4	Significant risk of child labor in operations and suppliers	Risk score	1/6	-1	0	0	1/12	1/12
Soci-4.5	Significant risk of forced or compulsory labor in operations and suppliers	Risk score	1/6	-1	0	0	1/12	1/12
Soci-4.6	Human rights impacts in the supply chain	Risk score	1/6	-1	7	3	0	1/6
Soci-5	**Negative impacts on local communities**	**Risk score**	**1/6**				**1/12**	**1/12**
Soci-5.1	Negative impacts on local communities	Risk score	1/3	-1	3	6	1/3	0
Soci-5.2	Risks related to corruption	Risk score	1/3	-1	0	0	1/6	1/6

Table E.1: Results of comparing the jewellery industry and the catalytic converter industry by making use of the framework (continued)

ID	**Name**	**Units**	**Weight**	**Impact**	**Jewellery industry**	**Cat. conv. industry**	**Jewellery industry score**	**Cat. conv. industry score**
Soci-5.3	Negative impacts on society in the supply chain	Risk score	1/3	-1	7	5	0	1/3
Soci-6	**Health and safety impacts of products and services**	**Risk score**	**1/6**				**1/12**	**1/12**
Soci-6.1	Health and safety impacts of products and services	Risk score	1/2	-1	1	5	1/2	0
Soci-6.2	Sale of banned or disputed products	Risk score	1/2	-1	6	4	0	1/2

Table E.2: Frequency distribution data of index results taking input uncertainty into account

Index value	Jewellery industry	Cumulative frequency	Cat. conv. industry	Cumulative frequency
Economic index				
0	69	69	0	0
1/12	49	118	0	0
2/12	2709	2827	0	0
3/12	1849	4676	0	0
4/12	2989	7665	7	7
5/12	1526	9191	118	125
6/12	684	9875	684	809
7/12	118	9993	1526	2335
8/12	7	10000	2989	5324
9/12	0	10000	1849	7173
10/12	0	10000	2709	9882
11/12	0	10000	49	9931
1	0	10000	69	10000
Environmental index				
0	1	1	27	27
1/12	7	8	132	159
2/12	21	29	623	782
3/12	61	90	1365	2147
4/12	240	330	2531	4678
5/12	656	986	2424	7102
6/12	1912	2898	1912	9014
7/12	2424	5322	656	9670
8/12	2531	7853	240	9910
9/12	1365	9218	61	9971
10/12	623	9841	21	9992
11/12	132	9973	7	9999
1	27	10000	1	10000

Table E.2: Frequency distribution data of index results taking input uncertainty into account (continued)

Index value	**Jewellery industry**	**Cumulative frequency**	**Cat. conv. industry**	**Cumulative frequency**
Social index				
0	0	0	0	0
1/12	0	0	0	0
2/12	0	0	0	0
3/12	1724	1724	0	0
4/12	3113	4837	15	15
5/12	3311	8148	258	273
6/12	1579	9727	1579	1852
7/12	258	9985	3311	5163
8/12	15	10000	3113	8276
9/12	0	10000	1724	10000
10/12	0	10000	0	10000
11/12	0	10000	0	10000
1	0	10000	0	10000