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Comparing the Sustainable Development Potential of Industries: A Role for Sustainability Disclosures?

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Abstract: Governments often seek to facilitate sustainable growth through the targeted support of specific industries that are deemed to have considerable sustainable development potential. However, the selection of appropriate sectors generally relies on resource-intensive assessment processes. With the recent flood of sustainability information into the public domain, there appears to exist an opportunity to use this information to improve the efficiency of the initial stages of evaluating target industries. This work investigated the development of a framework that makes use of public sustainability disclosures to rapidly compare industries in terms of their sustainable development potential. The goal was to evaluate whether such a framework could usefully provide a way to prioritize the execution of more in-depth feasibility studies on industries showing superior sustainable development potential. The developed framework was based on the Global Reporting Initiative's G4 Sustainability Reporting Guidelines and makes use of 18 indicators to compare industries in terms of various triple bottom line considerations. The framework was applied to a case study of the platinum industry in South Africa to establish its usefulness, potential and limitations. The framework facilitated a reasonably holistic, transparent and easily interpretable comparison of industries. However, its consideration of industry fit in the local economy, expected development trends and quantification of indirect economic impacts were found to be areas that could be improved. Some of these concerns might be overcome by the improved availability of public information in the future.

Keywords: sustainability; global reporting initiative; framework; sustainable development; industrial development; feasibility studies

1. Introduction

Governments often seek to spur local development through targeted support of specific parts of the economy that are deemed to have high developmental potential. Such endeavors may find expression in national development strategies that identify target sectors, industries or value chains. These strategies usually involve the promotion of investment in the identified areas, generally facilitated by a government-mandated investment promotion agency (IPA) [1]. IPAs are receiving increasing attention in the global policy realm as governments seize upon the positive correlation between investment promotion and increased foreign direct investment (FDI) [2,3].

The target sectors, industries or value chains need to be selected such that they align with the government's strategic goals and provide the best possible outcomes for a given investment. Due to the complexity and enormous number of considerations to be taken into account when considering an investment decision, an iterative, multiphase feasibility assessment process is typically applicable. Such a process involves the collection and examination of information on each alternative to sequentially narrow down the options until the final alternative(s) can be selected. The resources invested and, as a result, the information available on each alternative, as well as the value created by such assessments typically increase with each consecutive phase, while the focus simultaneously narrows. Due to the iterative and multiphase nature of this process, a substantial amount of resources—time, effort and funding—is generally invested in the feasibility assessment process [4,5]. This has been exacerbated by the evolution of justifying investment decisions from being primarily based on maximizing economic value creation to systematically considering environmental and social factors as well [6,7].

Policymakers often depend on tools and instruments, such as indicator frameworks, to rapidly identify the most appropriate targets for investment promotion to maximize the return on investment [8]. All of these tools, and any feasibility assessment study, rely on the reliable collection of data. It therefore follows that simplifying and/or shortening the data collection process may result in substantial savings in terms of resources invested in the study.

One opportunity to improve the efficiency of gathering data for feasibility studies, may lie in the recent flood of sustainability information into the public domain. This information is a result of the ever-increasing global emphasis on sustainable business strategies and corporate social responsibility, with corporate sustainability reporting subsequently becoming a global norm [9]. An opportunity exists to make use of this sustainability information in a structured (and even automated) manner to support the improved and rapid decision-making regarding investment in the development of new industries during the initial stages of investment feasibility studies [10]. This has the potential to dramatically reduce the time required for such studies and to greatly improve the information available to entities like IPAs for comparing different development opportunities in the early stages of selecting target sectors. This may be particularly pertinent for developing countries, where the resources available for undertaking such feasibility studies may be even more constrained.

This exploratory study therefore aimed to evaluate the potential of using publicly available sustainability information for comparing different development opportunities in terms of the Triple Bottom Line (TBL) [11]. This was accomplished by developing a feasibility comparison framework that uses well-known sustainability indicators to facilitate the rapid, high level comparison of potential development opportunities, as would typically be useful during the initial stages of identifying viable industries for development in the local economy. This framework was then tested by applying it to a case study on the platinum industry in South Africa to establish its usefulness, potential and limitations.

The paper emphasizes the positive change that can potentially be attained by creatively using the growing amount of sustainability information in the public domain. Simply disclosing sustainability information will not affect change. The academic community thus plays a critical role in operationalizing sustainable development by developing innovate methods that make use of available information (in this case, sustainability disclosure) to guide decision-making. The rest of this article provides an overview of the related literature (Section 2), outlines the research methodology that was followed (Section 3) and presents the proposed assessment framework (Section 4). The results of the case study are then presented in Section 5, followed by a reflection on the utility, potential and shortcomings of the framework (Section 6) and concluding remarks (Section 7).

2. Literature

This section presents a high-level overview of the fundamental underlying aspects considered in the development of the framework. The section commences with a very brief overview of some notable, recent work on the definition of sustainability assessment (Section 2.1). Section 2.2 then presents an overview of relevant past work in terms of tendencies in sustainability reporting and the use and aggregation of sustainability indicators. This is followed by a discussion of how such indicators, structured into indicator frameworks, may be used for comparing sustainable development potential (Section 2.3).

2.1. Sustainability Assessment

A vast literature exists regarding sustainability assessment and an exhaustive discussion of this literature will therefore not be attempted in this paper. In a very recent paper, Pope et al. [12] acknowledges that due to the rapid expansion of the sustainability assessment practice, the field has become very confusing and they therefore developed a new descriptive conceptual framework for sustainability assessment to aid in the navigation of the field. Bond et al. [13] provides an insightful exposition of what was considered the state of the art of sustainability assessment in 2011. The five aspects that are highlighted for inclusion in sustainability assessments are also considered in the current work. Along the same vein, Gasparatos and Scolobig [14] present a useful overview of the typology of sustainability assessment tools. These authors also present what they found, from literature, to be the five desirable features of sustainability assessment. Although these features differ substantially from the five aspects discussed by Bond et al. [13], they are also explicitly or implicitly included in the work presented in this paper.

2.2. Sustainability Indicators and Aggregation

Sustainability reports are now widely published by companies who seek to voluntarily, or due to local reporting regulations or incentives, disclose information on the sustainability performance of the company. The tendency of companies to publish such reports are influenced by various factors ranging from size and profitability to media exposure and customer proximity. Several studies investigate these tendencies [15–22] with some referring to the legitimacy, stakeholder or agency theories for explanation [17,20,23]. The potential value of such reporting has become increasingly visible, with at least one study finding that sustainability disclosures are valued by investors [18]. It has also been found that such disclosures are positively related to firms' market value. This seems to suggest that leading companies value such disclosures for their ability to signal that they strive to act responsibly [15–21]. Brammer and Pavelin [24] further report that high quality disclosures of environmental information are primarily associated with larger firms and those in sectors related to environmental concerns.

Sustainability indicators, widely used in sustainability reports, aim to reduce the amount of complex interrelationships in our dynamic environment to a manageable amount of meaningful information [25–27]. 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 (often large) number of indicators to measure progress in all the dimensions of sustainable development [25,28].

The usefulness of many individual indicators in decision-making is often limited by the inability of the user to draw an objective and transparent conclusion by considering all the individual indicators. It may therefore be desirable to be able to combine all the indicator values into a single value that captures the essence of all the individual values [29]. The potential value of such aggregated indicators has attracted some research attention and various approaches to aggregate indicators have been proposed [29–33]. The aggregated, single metric thus obtained is commonly referred to as a (composite) sustainability index. Sustainability assessment frameworks often make use of sustainability indicators that are aggregated into indices, to facilitate the quantification of sustainability performance (see, for example, [25,27,28,34]).

Critics warn, however, that the aggregation of indicators can lead to deceptive results due to the inherent subjectivity of the aggregation process [27,35]. Furthermore, Waas et al. [28] note 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 ...". It is therefore important to follow a process that is as transparent and objective as possible in the development and use of composite indices.

2.3. Comparison of Sustainable Development Potential

In its "*Investment Promotion Handbook for Diplomats*", the United Nations Conference on Trade and Development (UNCTAD) [1] provides a schematic illustration of the process of identifying sectors and the development and implementation of an investment promotion strategy. This schematic illustration is reproduced in Figure 1. Steps 4–6 in Figure 1 are of particular relevance to the present work. These steps comprise the setting of selection criteria and objectively and transparently assessing the alternatives using these criteria to select the most desirable alternative.

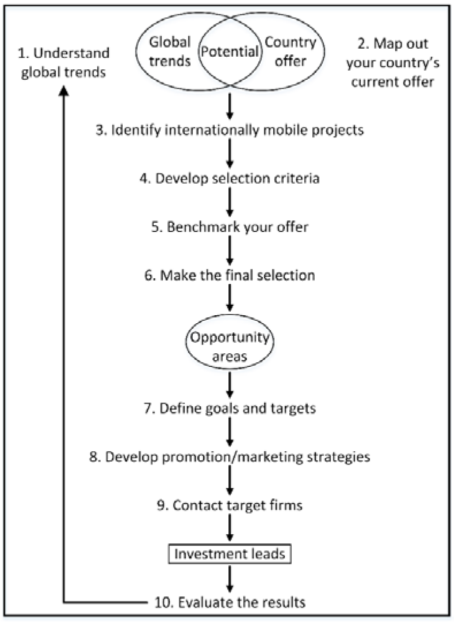

Figure 1. Strategy development and implementation [1].

The UNCTAD developed an indicator framework that addresses steps 4–6 in Figure 1. More specifically, the framework is aimed at informing the process of establishing policy priorities and focusing limited resources on specific sectors, value chains or value chain segments. The framework, however, is focused on maximizing economic value added and job creation from private sector investment, with only a few other sustainable development considerations incorporated. As a result, the framework neglects some aspects of sustainable development and sustainable value creation across all dimensions of the triple bottom line.

Many indicator frameworks aimed at sustainability assessment, which consider the TBL dimensions more comprehensively, can be found in literature. Chen et al. [36] presents a short review and evaluation of tools that can be used for factory sustainability assessment, while Grunda et al. [37] presents an overview of 30 papers published between 1997 and 2010 that focus on organizational sustainability evaluation, assessments and measurement. Table A1 in Appendix A presents a brief summary of some further relevant works that make use of indicators to quantify and assess sustainability.

Further, many approaches have been described that aim to extend analysis beyond simply assessing sustainability and to include the selection of optimal alternatives. Gonzalez et al. [38] introduces 38 works that propose decision-making models and tools to address sustainability challenges in integrative ways. Most of these methods, however, focus on operational-level decisions such as the selection of optimal technologies for improving the energy efficiency of a process [39–41], reducing waste generation [42,43] or enhancing overall sustainability of a process [44–47].

In a work more strongly focused on policy-level assessment, Fitzgerald et al. [48] presents a novel quantitative method that makes use of a list of indicators to evaluate policies aimed at enhancing urban sustainability. In a work also aimed at policy-level assessment, Greening and Bernow [49] argue strongly for the use of multi-criteria decision-making (MCDM) methods in integrated assessment frameworks to be used to inform the comparison of environmental or energy policy alternatives. Further, some methods have been developed to compare the sustainability of countries or regions. Kouloumpis et al. [50], for example, make use of fuzzy logic to compute the overall sustainability of more than 100 different nations. Similarly, the United Nations Commission on Sustainable Development (UNCSD) [51] developed guidelines for using a set of 58 national indicators to measure countries' progress toward sustainability goals.

From the works mentioned in the preceding paragraphs (and in Table A1), it is clear that sustainability assessment has received substantial research attention. It is also clear that most authors focus on organization- or operation-level assessment of sustainability, with some focusing on a national-level assessment of sustainability. Industry- or sector-level assessments, however, appear to be neglected. Furthermore, industry- or sector-level assessment of sustainability may be especially useful in terms of strategic decision-making by governmental policymakers, such as IPAs, seeking to target specific sectors to be established or further developed in the national economy. Despite this, little literature is available regarding the quantitative comparison and selection of different industries or sectors (by, for example, using a set of predefined indicators, as used for organization-level assessment) to be prioritized in terms of national development policy. This work thus investigates the use of publically available sustainability information collected at the company level, scaled to the industry/sector level to support the sustainability assessment of industries/sectors at a strategic policy level. The following section describes the methodology that was followed to develop a framework that achieves this.

3. Method

The development of the proposed analysis framework followed a methodology consisting of three phases. This section serves to outline these phases and the steps each comprise. The specific structure choices made in each step and the resulting framework are discussed in the following section (Section 4).

Figure 2 illustrates the methodology followed in the development of the framework. Phase 1 served to gain an understanding of literature relevant to the research (as summarized in Section 2). Phase 2, the development of the framework, was based on the approach described in the Handbook on Constructing Composite Indicators [35]. The results of this phase are presented in Section 4. The application of the developed framework to a case study to test its functionality and usability then followed in Phase 3. This results from this case study is presented in Section 5. Based on the outcomes from this methodology, Section 6 provides a discussion of the implications of the results.

Following the literature review conducted in Phase 1, Phase 2 comprised six steps. It started with the selection of an existing reporting framework to serve as basis for the framework developed in the present work. Such a framework serves as the main repository from which well-defined, -structured and -tested indicators were selected, while simultaneously ensuring that indicators are used for which published data are already available. Section 4.2.1 further elaborates in this regard. Following this step, Steps 2.2–2.4 consisted of setting criteria for indicator selection, applying these criteria to the base framework to sieve out indicators that may be superfluous for our purpose and defining the scope and grouping of the selected indicators in the new framework. Sections 4.2.2 and 4.2.3 present more details on the execution of these steps. Having selected and structured the indicators to be used, Step 2.5 then aimed to select the appropriate aggregation scheme in to generate, from the underlying indicators, a single composite index for each dimension of the TBL. Sections 4.2.4 and 4.2.5 discusses the normalization, weighting and aggregation methods used to accomplish this. Phase 2 was concluded with validation of the developed framework by discussion with experts and collection of their inputs regarding the functionality, contribution and usability of the framework in the form of a questionnaire.

As indicated in Figure 2, these inputs were used to revise the indicators included in the framework, as well as the scope and grouping of the indicators. Section 4.2.6 elaborates on the execution of this step.

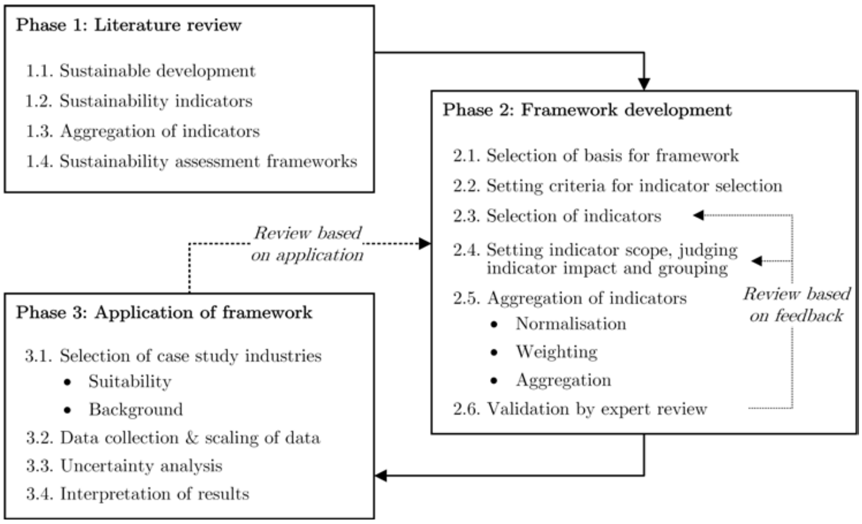

Figure 2. Overview of the methodology followed in the development of the framework.

Upon completion of Phase 2 (the development of the framework) the functionality and usability of the framework was further assessed by application to case study industries in Phase 3 of the methodology. Phase 3 began with the selection of suitable case study industries to be compared by using the framework (Section 4.3.1). Having selected the case study industries, collection and scaling of the required input data could commence. Sections 4.3.2 and 4.3.3 discuss the execution of these steps. An uncertainty analysis was then conducted to quantify the uncertainty associated with the results generated. This was done to ensure the appropriate interpretation of results given missing and incomplete information used to generate results. The details of the uncertainty analysis are discussed in Section 4.3.4. This is followed, in Section 5, by a presentation and interpretation of the results generated using the framework. The interpretation of the results aimed to allow the assessment of the functionality and usability of the framework and the potential utility of the results it generates.

Phase 2 of the methodology encompassed the steps in which the main structure, and therefore the inherent properties, of the framework was developed. The different methods that were considered in each step are outlined in Table A2 in Appendix A, along with the prominent literature sources in which the listed methods are discussed. The selection of a basis for the framework and setting the criteria for indicator selection (Steps 2.1 and 2.2) are unique to the requirements of any particular study and therefore, no methods or literature sources were indicated for these steps. Similarly, there are no specific methods for setting indicator scope, judging indicator impact and grouping indicators (Step 2.4) in literature, although some sources discuss these steps in general [31,33,35,52].

4. Proposed Assessment Framework

Following the methodology described in Section 3, a framework that uses publicly available sustainability information to compare the sustainability performance of different industries was developed. This section presents the decisions made in the development of the framework. The discussion starts with an outline of the structure of the developed framework (Section 4.1). This is followed by an elaboration on the decisions made in the construction of the framework (Section 4.2), with reference to the steps outlined Section 3. Each of these decisions has a potentially significant impact on the results generated by the framework and the rationale for the choice of each is therefore also discussed.

4.1. Framework Structure

Figure 3 illustrates the comparison of potential development opportunities as facilitated by the framework. Similar to most of the frameworks that make use of aggregated indicators discussed in Section 2 and listed in Table A1, notably Zhou et al. [33] and Krajnc and Glavic [31], the framework relies on sequential aggregation steps to move from sub-indicators to composite indices. Specifically, the framework is composed of sub-indicators (forming the bottom framework level), which are combined to form indicators (forming the intermediate framework level). These indicators are in turn aggregated to produce a single composite indicator, or index, for each dimension of the TBL (forming the top framework level). This allows the comparison of different potential industries at the hand of only three indices. To limit information loss and the subsequent increased inaccuracy, the three indices are not aggregated further to produce a single overarching composite indicator.

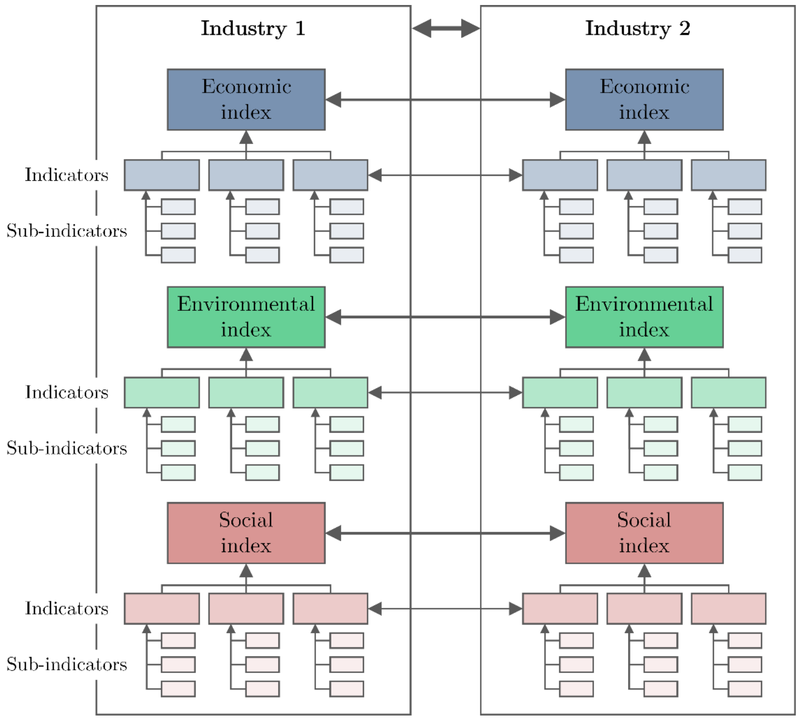

Figure 3. Framework structure facilitating comparison of potential development.

The framework was further designed to have a symmetrical indicator structure thereby ensuring no distortion of the weights of indicators in the different dimensions (Section 4.2.4 elaborates further in this regard).

Finally, 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.

4.2. Framework Development

The decisions made during Phase 2 of the research methodology outlined in Figure 2 (Section 3) are discussed in depth in this section. Reference is made to the: (i) framework foundation; (ii) selection of indicators; (iii) scope and grouping of indicators, as well as the judgement of impact; (iv) weighting of indicators; (v) aggregation of indicators; and (vi) validation of the framework.

4.2.1. Foundation of the Framework

The framework depends on the use of quantitative data to compare different development opportunities in an objective manner. The increasing amount of sustainability information that is available in the public domain was 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 developed framework to find organizations active in the relevant industries elsewhere in the world and use the data which these organizations report according to the guidelines of the existing framework. This data can be used as 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 guideline has several advantages. Firstly, the required input data is available and easily accessible. Moreover, the data is already in the right form, eliminating or reducing the need to adjust the data. Secondly, the transparency and accuracy, and therefore credibility, of data are already proven to be acceptable.

Therefore, a decision was made that the framework will be based on one or more existing sustainability reporting frameworks or guidelines. In a previous work by the authors [10], five prominent international sustainability reporting frameworks were compared, using several criteria, to determine which of these frameworks would be most suitable to be used to compare the sustainability of different industries. It was found that the Global Reporting Initiative's (GRI) Sustainability Reporting Guidelines was the most suitable framework to be used in a comparison model, based on its almost universal global acceptance, the standardized nature of the indicators it uses and the comprehensive scope of its indicators. Based on this result, the GRI G4 Sustainability Reporting Guidelines were selected to serve as basis for the present framework.

4.2.2. Selection of Indicators

Using the GRI G4 Sustainability Reporting Guidelines as foundation for the present framework, indicators to be used in the framework had to be selected from those used in the GRI G4 guidelines. The selection of the underlying indicators was of particular importance as the strengths and the weaknesses of a composite indicator largely derive from the quality of the indicators it is composed of [35]. As the indicators used in the present framework are selected from the GRI G4 guidelines, which makes use of well-defined and tested indicators, the quality of the underlying indicators in the present framework are implied.

Niemeijer [53] states that the underlying indicators used to construct a composite indicator are generally selected according to either the data-driven approach (where data availability is the central selection criteria) or the theory-driven approach (where it is attempted to select the best possible combination of indicators to describe the system, also taking the availability of data into account). Zhou et al. [33] adds a third approach: the policy-driven approach, where indicators are selected specifically to comprehensively measure and assess the impact of a certain policy.

A theory-driven approach, with specific emphasis on using indicators for which data is available, was used in the present work. Making use of a theory-driven approach ensured all the dimensions of the triple bottom line were addressed, as is required in a comprehensive assessment of sustainable development potential. Further, taking the availability of data into account ensured that data collection would remain rapid and relatively simple, as the rapid comparison of opportunities is one of the objectives of the developed framework.

As a result of the nature of the developed framework, there were two specific requirements that had to be met by indicators to be of use in the present framework. Firstly, each indicator had to be generalizable for an entire industry, as the framework aims to compare entire industries. A single value, representative for the entire industry, should therefore be attainable for each indicator in the framework to allow comparison with the value of that indicator for another industry. Secondly, each indicator had to be applicable to an industry that is yet to be established. The framework specifically aims to facilitate the comparison of potential industries to facilitate better decision-making in terms of which industries to develop in the economy. Indicators measuring changes in performance, for example, reductions in material or energy use were therefore not deemed applicable. Such indicators are useful when assessing sustainable development progress by using the GRI G4 Sustainability Reporting Guidelines, for example, but as industries that are not yet established are to be assessed with the framework developed in this study, only absolute measured were considered.

Further, in the development of the framework it was considered important that the framework is comprehensive and objective enough to produce dependable results, but remains easy to use and swiftly produces rapidly 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, but would add to the time required for gathering information. Summary indicators that can integrate the results of other indicators were thus favored over indicators that provide a more detailed breakdown of information covered by other summary indicators. Including such summary indicators meant that detail indicators could be excluded without distorting the aggregate results and reducing the total number of indicators sampled.

The G4 guidelines make use of 91 indicators, consisting of 9 economic, 34 environmental and 48 social indicators. By application of the above-mentioned criteria to the G4 guidelines (i.e., removing all indicators that are either not generalizable for an entire industry or not applicable to an industry yet to be established) the number of indicators were reduced from 91 to 37.

A further five indicators were removed in accordance with the aforementioned objective of limiting the number of indicators addressing each aspect and preventing over-emphasizing 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 organization. Indicators presenting the energy intensity or greenhouse gas emissions intensity, for example, merely presents information already captured by other indicators (measuring energy consumption and the mass of greenhouse gas emissions in this case) in ratio form. Although this information aids the user by providing another perspective using the same information, it does not add new information or improve the accuracy of the results produced by the framework. These indicators were therefore deemed excessive in the framework developed here.

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. These preliminary indicators included in the framework were later adjusted based on the feedback received in the validation process (discussed in Section 4.2.6). To assess the coverage of the selection, the indicators were also assessed in terms of their linkage to the sustainable development goals (SDGs) as indicated in Table A4, Appendix C. A brief explanation of each of the final exclusions is provided in the Supplementary File S3.

4.2.3. Indicator Scope, Grouping and Judgement of Impact

The framework was aimed at the 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 organization-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 generalization of the indicators to represent information for a newly established industry, as opposed to representing retrospective information of only one organization. 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 organizations within an industry. As such, in the present framework, indicator G4-EN8 measures only the mass of water withdrawn (irrespective of the source).

Further, as the 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. Thus, in the framework, risk and impact scores were used to quantify indicators that measure predominantly qualitative aspects. These quantifications in terms of risk and impact scores were accomplished by making use of a risk quantification matrix. Risk matrices are commonly used in the quantification of risk in a variety of fields, most prominently in project management [54–56]. In this matrix, 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). A combination of the perceived potential impact and the likelihood of that impact occurring determines the risk or impact score associated with a case.

Sub-indicators measuring similar aspects had to be grouped together in order to make the process of allocating weights more accurate. This helped prevent over-emphasizing 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 one measures. After revision of the scope of all the indicators to be included in the framework, however, the grouping of some of the indicators were adjusted to ensure a logical framework structure. For example, Indicator G4-LA15 in the G4 guidelines (Supplier assessment for labor practices) was considered similar to indicators G4-HR3 through -HR6 and -HR11 (all referring to different human rights assessments). All these indicators were therefore grouped together to form indicator Soci-4 (Human rights assessments) in the framework.

Finally, the contribution measured by each indicator has to be judged in order to establish which indicators indicate positive impacts and which indicate negative impacts [33]. The nature of the impact has an influence on the subsequent normalization and aggregation steps (discussed further in Section 4.2.5). For example, the impact of generating higher financial earnings can be considered positive outcome, while the impact of producing higher greenhouse gas emissions can be considered to be a negative outcome.

4.2.4. Weighting of Indicators

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 emphasized in a composite index. Weighting of indicators can be derived from statistical models or from participatory methods (see Table A2 in Appendix A) [35]. However, it is most common to use equal weighting (EW) of all indicators [29–31].

In the developed framework, 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. The sub-indicators for every indicator are also 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 weights of the sub-indicators depend on the number of sub-indicators of which an indicator is composed. For example, indicator Soci-4 is composed of six sub-indicators (therefore weighting $\frac{1}{6}$ each) while indicator Soci-5 is composed of only three 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 $\frac{1}{6} \times \frac{1}{3} = \frac{1}{18}$. Equal weighting of all indicators, coupled with the symmetrical indicator structure (six indicators measuring each dimension of the triple bottom line), implies that all dimensions of the triple bottom line are assumed to be of equal importance. Further, 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 is typically desirable with sustainability indicators where all the dimensions are of equal importance to ensure progress toward balanced sustainability (as pointed out by, amongst others, Brandi et al. [30], Krajnc and Glavič [31] and Lozano [57]).

4.2.5. Aggregation of Indicators

Several different aggregation methods can be used. Linear aggregation, typically calculated as the weighted sum of the normalized indicators, is widely used due to its simplicity, transparency and accessibility. Geometric aggregation, calculated as the product of the normalized individual indicators each to the power of its weight, is also used in some cases. However, both these aggregation methods are compensatory in nature and therefore indicator weights express substitution rates (trade-offs) between indicators and not the relative importance. This compensatory logic, meaning that sufficiently good performance of some indicators can compensate for poor performance of others (referred to as compensability), is often an undesirable property [33,35,58].

To overcome the problems regarding compensability and the meaning of weights, a non-compensatory multi-criteria (NCMC) approach can be used. NCMC aggregation 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 [35].

Apart from addressing the problems regarding compensability and the meaning of indicator weights, NCMC aggregation also allows the use of both quantitative and qualitative information and does not require normalization of data, thereby limiting subjectivity in the aggregation process [58]. 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 [35].

A non-compensatory multi-criteria (NCMC) aggregation logic was deemed most appropriate for the framework in this study. This choice is based on several considerations. As noted in the Handbook on Constructing Composite Indicators [35], multi-criteria problems, such as the comparison in the present framework, cannot be solved to find a single solution optimizing all the criteria at the same time (the so-called "utopia solution"). Instead an acceptable solution, allowing compromise, has to be found. However, compensability in the aggregation process might favor solutions that excel in only one or a limited number of dimension. NCMC aggregation is superior to the other methods in this respect as it does not reward outliers, since 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. Cognizant of its shortcomings and the need to inspect the underlying indicators separately when drawing conclusions, NCMC aggregation, in which consistent performance is rewarded, was deemed most suitable for the purposes of the proposed framework.

Furthermore, the fact that information regarding the magnitude of indicator values is not captured in the aggregation process and no normalization is required allows the user to compare the composite indices for different dimensions. As only weights, which 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 normalized 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 different dimensions of sustainable development.

4.2.6. Validation of the Framework

The aforementioned 32 preliminary indicators were used in the first iteration of the process in which the framework was first reviewed based on inputs from experts. The framework was then tested further by application to a case study.

To validate the framework, four experts were identified by discussion with the project leader and by recommendation from experts already contacted in the process of developing the framework. These experts represented several perspectives, including sustainability research, the private sector involved in metal beneficiation, as well as research on the economic beneficiation of metals in South Africa. Experts with this variety of expertise were purposely 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. The 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 to provoke an elaborate explanation of any perceived shortcomings. Among others, the questionnaire requested feedback on whether the framework was comprehensive enough and whether the experts considered the framework as potentially useful. Experts were also encouraged to voice any concerns or potential shortcomings that they noticed.

The consultation process with the experts produced several insights that were used to improve the indicators included in the framework. A summary of the final indicators included in the framework (after incorporation of the insights from the experts) is presented in Table A3 in Appendix B.

4.3. Case Study Methodology

Applying the developed framework to case study industries formed the third phase of the methodology used in this project (as illustrated in Figure 2) and served to test the utility of the framework and identify the shortcomings of its use. This phase therefore formed an important part of the process of validating the framework and the results it generates. It also enables the analysis of the strengths and weaknesses related to the use of sustainability indicators in the analysis of industries.

4.3.1. Case Selection

The first step in the application of the framework to a case study was the selection of appropriate industries to be compared in the case study. Many industries could be used to illustrate and test the utility and shortcomings of the framework. However, it was important to use industries for which the relevant information, of sufficient quality, was readily available (generally implying that globally well-established industries were favorable). It was further regarded to be of value if the case study industries were not only relevant in terms of validation of the framework, but also in terms of development in a country.

Given the increasing drive of several (mineral rich) developing countries to develop industries that increase the local beneficiation of mineral resources, mineral beneficiation industries were an ideal case study [59,60]. Platinum beneficiation was specifically chosen as platinum is used in a wide range of well-established industries globally, with accurate information generally easily attainable for many of these industries. Having selected platinum as a case study, South Africa was chosen as the focal region, as platinum is of specific economic importance to the country. South Africa is responsible for about 70% of annual global platinum production [61]. However, 89.5% of the platinum produced in 2013 was exported in the form of non-beneficiated metal [62]. The South African government has undertaken to promote the local beneficiation of its mineral resources, including platinum, in order to capture more value from these resources [63]. As such, the beneficiation of platinum in South Africa was an ideal and relevant case on which to test the utility of the framework, with the results of potential use to policymakers.

The catalytic converter industry is especially well suited as it is the largest platinum consuming industry globally [61] and a catalytic converter manufacturing industry is already established in South Africa. A large number of 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 also recognized at policy level [63]. The catalytic converter industry was therefore selected as the first case study industry.

The platinum jewellery industry is the second largest consumer of platinum globally [61] and therefore has advantages similar to those of the catalytic converter industry in terms of availability of information. Further, development and integration of platinum jewellery fabrication capabilities with the fabrication of gold and diamond jewellery in South Africa is also being encouraged at policy level [63]. The platinum jewellery industry was therefore selected to be the second case study industry.

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 could therefore not be gathered and the fuel cell industry could therefore not be used as part of the case study. This problem highlights an important drawback of making use of publicly available sustainability information in the framework as emerging industries are unlikely to have suitable information available for analysis. Thus, only the catalytic converter and platinum jewellery industries were analyzed in the case study. Detailed maps of the production and use, respectively, of platinum metal more broadly were also developed and are contained in the Supplementary Files Figures S1 and S2.

4.3.2. Data Collection

Large, pace-setting organizations were chosen to represent the case study industries in this study as these companies likely provide a close to best-case comparison, 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 the industry is indeed superior to the other (in general).

The organization chosen to represent the catalytic converter industry was selected because it is one of the largest global producers of catalytic converters, accounting for approximately a third of all catalytic converters used in light vehicles globally at the time of the study. This organization is globally acclaimed and has been producing catalytic converters for more than forty years. The organization further also has operations in more than 30 countries worldwide, 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. Similar to this organization, the organization chosen to represent the platinum jewellery industry is also considered one of the global leaders in its industry, with operations in 25 countries, which was once again seen as an advantage. At the time of the study, it was estimated that this organization accounted for more than three percent of global platinum consumption for jewellery purposes.

Having chosen the organizations that were used to represent the catalytic converter industry and the platinum jewellery industry, the authors proceeded to collect the required data from the organizations' annual financial and sustainability reports. 2014 was used as subject year for all data and calculations as this was the latest year for which sufficient data could be attained when the case studies were performed.

The data collection process was complicated in several ways. The first obstacle was that different organizations 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 organizations do not report all the indicators that form part of the GRI reporting guidelines as all disclosures are voluntary. Organizations may exclude specific indicators for various reasons. For example, companies may only report indicators that are deemed material to their specific operations, exclude indicators that are not measured adequately for their operations or exclude indicators that disclose information that may considered sensitive or proprietary. As a result, data could not be found for indicators Envi-1.1, -1.2, -3.2, -4.1, -4.2, -5 and Soci-3 for one or either of the compared industries.

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 [64,65]. However, the imputation of data will always affect the accuracy and the credibility of the composite indicator(s) in which that data is used [35]. For the present work, imputation of missing indicator values was not considered as 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 organizations. This meant that neither explicit nor implicit modelling could be used to estimate missing values.

Fortunately, the majority 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 did therefore not result in the complete neglect of that aspect, although that aspect was less fully described. Indicators Envi-5 and Soci-3 were, however, 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 meant that these aspects were no longer considered in the framework. 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 4.3.4).

The increased adoption of policies and regulations such as Directive 2014/95/EU of the European Parliament [66], which requires certain large organizations to include non-financial disclosures in their annual reports, is expected to result in an increase in availability of consistent and comparable sustainability information. Further, the concept of integrated reporting is drawing increased attention globally and it is becoming increasingly plausible that integrated reporting may become mandatory to many organizations in the foreseeable future. This would further increase the availability of sustainability information in the public domain and would foreseeably reduce instances in which indicators have to be excluded from the framework due to a lack of data for those indicators. Improvements in integrated reporting may also lead to the establishment of generally accepted auditing processes for disclosures that resemble those currently limited to financial auditing. This will support improved data reliability. The fact that these developments are still unfolding, clearly restricts the current applications of the proposed framework to only being used as an early stage pre-feasibility assessment aid. Furthermore, these developments may render the GRI G4 guidelines obsolete in future, meaning the framework proposed in this work would have to be substantially revised.

4.3.3. Scaling of Data

The data collected for each organization had to be scaled in two ways. Firstly, neither of the organizations 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 where relevant. Secondly, this data had to be scaled from organization- to industry-level, such that the data represent an entire industry and not only a single organization in that industry.

For both industries, the first scaling was based on the percentage of total sales contributed by the relevant portion of the organization’s operations. For the organization representing the jewellery industry, for example, it was calculated that 46% of the total sales reported by the organization was from the sale of platinum jewellery pieces. All subsequent indicator values that were dependent on organization 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%) during the sensitivity analysis in an attempt to account for the uncertainty in this assumption.

The second scaling of the data—from organization- to industry-level—was performed using two different methods. As 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, the mass of platinum used annually was used in this scaling. The mass of platinum consumed by the organization representing the case study industry 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 (5/3.3) 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 arbitrary and was varied uniformly between 3 and 7% in the uncertainty analysis. It will later be shown that this arbitrary assumption of 5% has little influence on the conclusions that can be drawn from the comparison.

The scaling for the catalytic converter industry was simpler as the catalytic converter industry is already established in South Africa and thus data of the revenue generated by 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 South African Automotive Industry Export Council [67] was used in conjunction with the total revenue generated from sales of catalytic converters calculated for the organization. The catalytic converter exports from South Africa amounted to 31.2% of the value of sales of catalytic converters by the organization. To represent an industry, all relevant indicators values for the organization were therefore scaled to 31.2% of their original values. The assumption was thus made that the catalytic converter industry remains as it is. Thus, the South African industry accounts for approximately 13 % of global production [62]. The case scenario thus compares the TBL impact of an industry already present with the potential TBL impact of a new industry based on experiences in other geographies. This illustrates the framework's ability to include the comparison of both existing (in the focal location) and potential (yet at least existing in other jurisdictions) industries.

4.3.4. Uncertainty Analysis

Various factors can influence the certainty associated with the outputs generated by application of the framework. 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 are some of the most prominent factors that introduce uncertainty. Uncertainty analysis was conducted to account for these uncertainties and thereby allow the user to take these into account when drawing conclusions from the framework outputs.

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. Uniform distribution functions were used for indicator values that were 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 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. As such, all possible outcomes were accounted for and given equal likelihood.

5. Case Study Results

This section presents the results generated by comparing the platinum jewellery industry and the catalytic converter industry using the framework. Figure 4 illustrates the outcome of the comparison. 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. The case study values used for all the indicators in the comparison of the industries are presented in Table A3 in Appendix B.

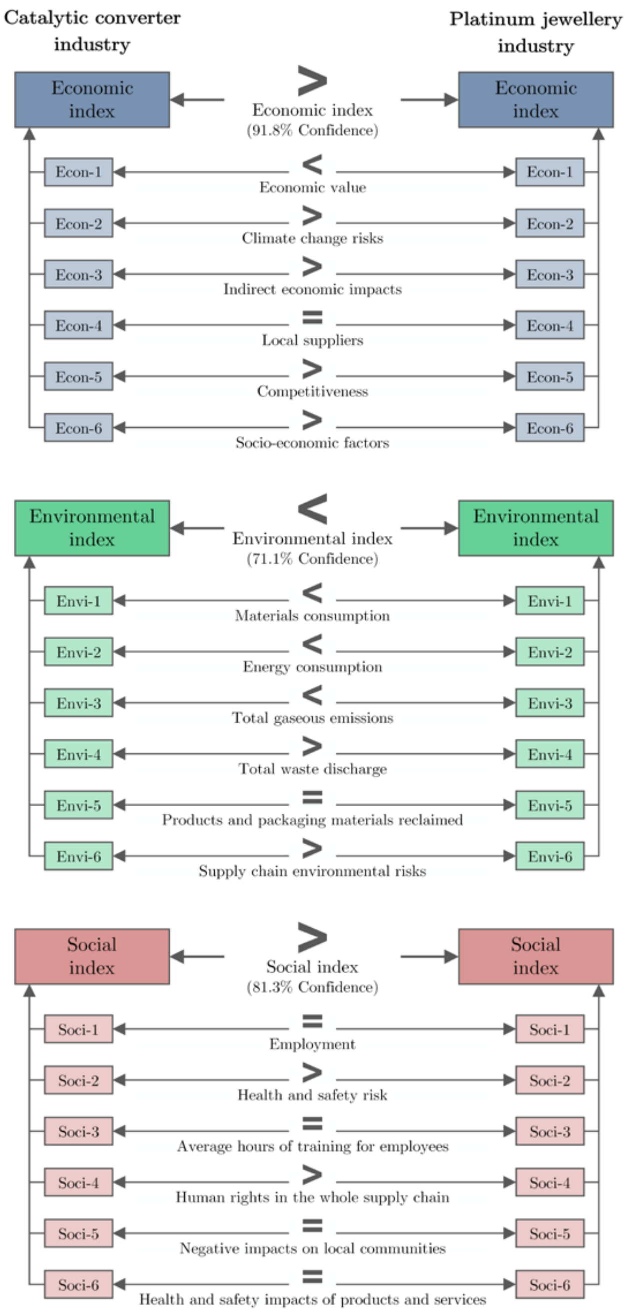

Figure 4. Results generated by using the framework to compare the platinum jewellery industry and the catalytic converter industry.

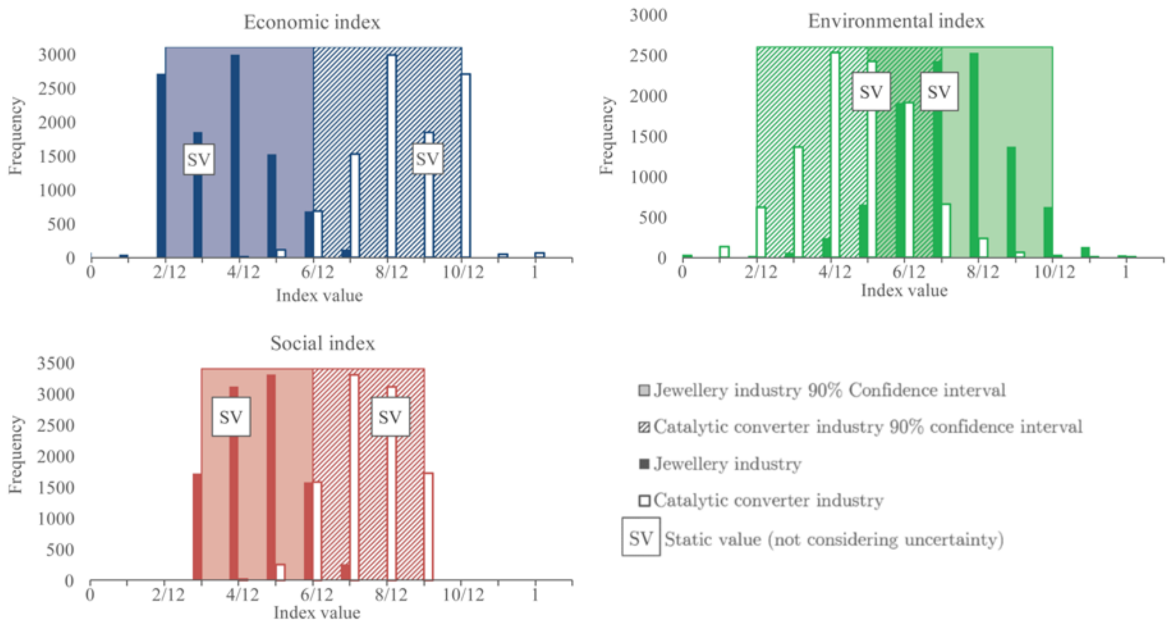

Figure 5. Index values and 90% confidence intervals for comparison of the platinum jewellery industry and the catalytic converter industry by using the framework.

Considering the economic index, the jewellery industry was superior in terms of indicator Econ-1 (Economic value) and the industries were rated equally in terms of indicator Econ-4 (Use of local suppliers). In the environmental dimension the jewellery industry was superior in terms of indicators Envi-1 (Material consumption), Envi-2 (Energy consumption) and Envi-3 (Total gaseous emissions) and the industries were rated equally in terms of indicator Envi-4 (Total waste discharge). Finally, in the social dimension the catalytic converter industry was superior in terms of indicators Soci-2 (Health and safety risk) and Soci-4 (Human rights in the supply chain), with the industries rated equally in terms of indicators Soci-1 (Employment), Soci-3 (Average hours of training for employees), Soci-5 (Negative impacts on local communities) and Soci-6 (Health and safety impacts of products and services).

Figure 5 presents the scores attained by each industry when the uncertainty 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. The scores were attained by adding the weight of each indicator in which a specific industry is superior to its score for that dimension (a total score of one could therefore be attained per dimension). The jewellery industry, for example, attained a total score of three twelfths ($1/6 + 1/12$) in the economic dimension as it was superior in terms of indicator Econ-1 and the industries were rated equally in terms of indicator Econ-4. The catalytic converter industry therefore attained a score of nine twelfths in the economic dimension.

5.1. Economic Index

The uncertainty analysis results indicate that the mode and median values for the economic index of the jewellery industry are both four twelfths (0.333), 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 eight twelfths (0.667) 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 six twelfths (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 (Figure 5) only meet at the six twelfths-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, the catalytic converter industry can be considered superior with 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 which implies that the scaling of the data from organization- to industry-level has little impact on the results for this dimension, as risk and impact scores are considered scale independent. 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.

5.2. 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. The index values of the industries are concentrated close to the center value of six twelfths where the industries are considered to have equal potential. It is therefore not surprising that the 90% confidence intervals of the industries overlap in the region between five and seven twelfths and that the confidence of the jewellery industry being superior in this dimension is only 71%.

The slight superiority of the jewellery industry in this dimension is a result of strong performance in indicators Envi-1 (Material consumption), Envi-2 (Energy consumption) and Envi-3 (Total gaseous emissions). These indicators are scale-dependent and the scaling of the organization-level data to industry-level therefore has a significant impact on the performance of the jewellery industry relative to the catalytic converter industry in this dimension.

5.3. 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 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 (Health and safety risk) and Soci-4 (Human rights in the supply chain). The industries are tied even at the other four indicators (with the exception of Soci-3, Average hours of training for employees, for which data could not be found). 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 thus only indicators Soci-1.1 and Soci-2 were scale-dependent. 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.

5.4. Brief Perspective on 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). 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 recognized in the Beneficiation Strategy published in 2011 [63]. 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. Catalytic converters can be seen as an interim solution that will only be useful until a better solution to the emission problem is found. However, internal combustion engines could remain important in the automotive industry in the medium term. 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. However, the relative rarity, useful properties and appearance of platinum means the likelihood of it becoming obsolete in the global jewellery market is likely slim. These developments highlight the need to not use the type of framework developed in this paper in isolation, but as another source of information in the decision-making process. The goal of the developed framework is to facilitate the efficient compilation of sustainability information as available in the public domain to provide a further dimension for decision-makers to consider and improve their overall decision-making process in relation to deciding on specific industries to support.

6. Discussion

Given the results from the case study, this section presents a S.W.O.T. analysis of the framework, based on observations that were made in the development of the framework and the application of the framework to the case study. Based on these observations, several recommendations are made for improvement of the framework, both in terms of theoretical rigor and practical usability. Observations are also made regarding the use of publicly available sustainability information to inform industrial policy in general.

6.1. S.W.O.T. Analysis of the Framework

Figure 6 presents a summary, in the form of a basic strengths, weaknesses, opportunities and threats (S.W.O.T.) analysis, of the utility and shortcomings of the framework as became apparent in the application of the framework and the subsequent interpretation of the results. The characteristics of the framework listed in Figure 6 are all inherent to the framework and its use and can therefore not be addressed easily. Recommendations for improvements are therefore discussed separately in Section 6.2.

Figure 6 lists several strengths of the framework. It is noted that the framework achieved the objective of facilitating the rapid comparison of different potential industries. The results generated by the framework can also be interpreted by inspection of the underlying indicators and sub-indicators that quantify each dimension. By such inspection, specific problem areas can be identified for subject industries, allowing effective consideration of these aspects in the decision-making process. Holistically strong performance by an industry is also rewarded, thereby ensuring that sustainability is considered as a whole and that industries that only perform well in some of the dimensions of sustainable development are penalized accordingly. Further, the uncertainty analysis, which is considered to be a crucial part of the working of the framework, contributes significantly to the credibility of the results and the accuracy of the interpretation of the results. Finally, a very notable strength of the framework is its generic nature that stems from the generic nature of the GRI G4 sustainability reporting guidelines on which it is based. This makes the framework applicable to all mineral beneficiation industries and industries outside this realm.

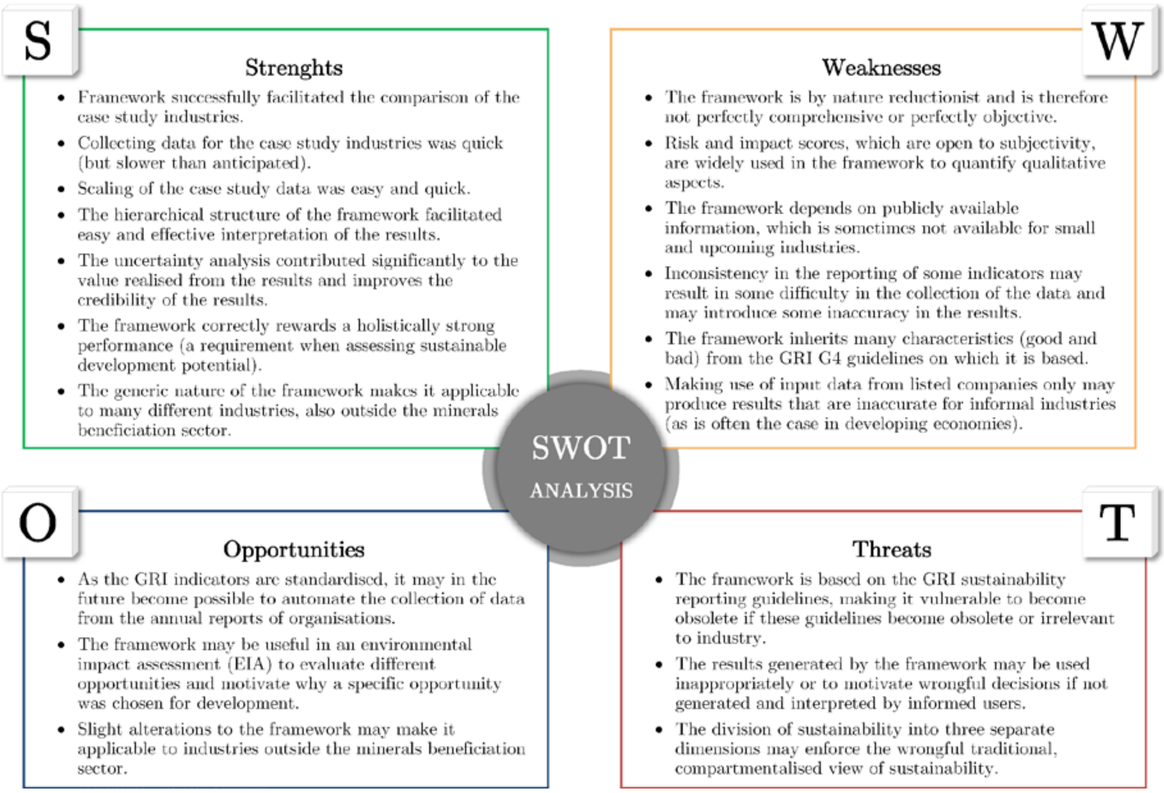

Figure 6. A summary of the utility and shortcomings of the framework in terms of a S.W.O.T. analysis.

Several weaknesses of the framework can also be identified. It can firstly be noted that the framework is by nature reductionist—a reduction or simplification of a complex reality—and therefore not perfectly comprehensive or -objective. The use of risk and impact scores are, for example, a subjective quantification of qualitative aspects. Further, the framework inherits many characteristics (good and bad) from the GRI G4 sustainability reporting guidelines on which it is based. The information reported according to the GRI G4 guidelines, which the framework uses as input data, for example, is typically reported by large, listed-companies, operating in developed (first-world) economies. Therefore, the results generated by using such input data may not necessarily be accurate for industries in developing (third-world) economies that may consist of small and/or informal enterprises. Further, peculiarities specific to some industries may be overlooked due to the generic nature of the framework and the indicators on which it is based. This underlines the fact that the framework can only be used for the very initial, scoping-phase filtering of development opportunities and that the thorough scrutiny of the results generated is of crucial importance. Further, the use of publicly available information is central to the working of the framework and therefore the framework cannot be used for industries if the correct data is not available (small, upcoming or informal industries, for example). Finally, inconsistency in the reporting of some indicators may result in some difficulty in the collection of the data and may introduce some inaccuracy in the results.

Figure 6 also identifies some opportunities and threats with regard to the framework. Firstly, the use of standardized, GRI indicators presents an opportunity in that it may become possible to automate the collection of data from the annual reports of organizations. However, this characteristic also presents a threat: the framework will become obsolete if the GRI sustainability reporting guidelines become obsolete or irrelevant to industry. Further, the generic nature of the framework may make it applicable industries beyond the initial scope of industries for which it was developed. The framework may even be useful in an application as far removed from its initial purpose as serving to evaluate different opportunities and motivate why a specific opportunity was chosen for development in an environmental impact assessment (EIA). However, a risk also exists that the results generated by the framework may be used inappropriately or to motivate wrongful decisions if not generated and interpreted by informed users. Finally, the division of sustainability into three separate dimensions may enforce the wrongful traditional, compartmentalized view of sustainability.

6.2. Recommendations for Improving the Framework

Several recommendations that can be made for improvement of the framework can be identified. 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, in its current form, take the expected trends in sector development and growth into account explicitly (this is left to be considered by decision-makers alongside the results generated by the framework). It might be sensible to incorporate this into the framework, such that industries with clear future upside in terms of development potential is favored 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, to aid in the quantification of the development potential of an industry. Some value chain structures may be more appropriate and favorable for development in some economies, based on existing industry structures or country-specific policy priorities.

Further, in the application of the framework to the case study industries, it has been noted that 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 organization. This will ensure that the input data is representative of the industry. 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 organizations from which data is gathered and mapping out of distortions and embedded effects in the data as a result of region-, country- or organization-specific events, or outlier events. Furthermore, it might be sensible to include the size of an industry in the allocation of risk or impact scores. This would ensure that potentially larger industries are penalized more for impacts than smaller industries, as impacts of the same severity for a smaller industry will likely be less detrimental overall.

Finally, it is recommended that the indirect economic impacts of an industry are emphasized more in the framework. Indicator Econ-3 quantifies indirect economic impacts in the framework and considers a vast array of impacts. This indicator quantifies, amongst others, the impact of the vertical, horizontal and lateral economic linkages generated by an industry, the impact of using the products and services of the industry, the impact of the industry on public infrastructure, 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 to facilitate better quantification of all the aspects it includes.

Indicators Econ-5 and Econ-6 quantify the potential competitiveness and socio-political fit of an industry. Local factors that may influence the competitiveness of an industry are considered, as well as the potential effects that political and regulatory factors may have on the success of the industry. Although considered implicitly, the fit of an industry in terms of the national and regional development goals of the target country are not taken into account explicitly. Developing an indicator that specifically quantifies this strategic fit of the industry in the target country may further improve the utility of the framework.

6.3. Discussion of the Use of Publicly Available Sustainability Information for Selecting Industries for Developement

Notwithstanding the challenges identified throughout the article, it seems clear that there could be substantial potential in using publicly available sustainability information to provide a first insight into the sustainability performance of different existing industries to inform development policy. However, the current challenges regarding data quality, data availability, level of disclosure (company, not product) and scope of disclosure (not according to country borders) still hinder the process from being easily automated and the granularity of the results from being ideal for informing policy. As the ubiquity and quality of public disclosures improve, some of these challenges will likely be resolved.

7. Concluding Remarks

The framework proposed (and publicly available sustainability information in general) has potential to be useful as a tool that aids in the analysis of developmental impact of industries. It is, however, also clear that much work is still required in terms of further expanding the proposed framework to include the aforementioned suggestions and identifying complimentary tools that can be used to make the results it generates more accurate and useful. The process of further developing and expanding the framework in its current form, will necessarily remain complex as many of the strengths that warrant the existence of the framework, such as its ease-of-use, are derived from its use of the GRI reporting guidelines as basis, but using these guidelines also introduces some inherent weaknesses. Improving the framework will therefore remain delicate in terms of finding a balance between, on the one hand, maintaining the ease-of-use of the framework and, on the other hand, ensuring the results it generates are sufficiently comprehensive and accurate, and therefore useful in decision-making. This article has introduced a novel structured approach to attaining sustainability information for IPA decision-making. It is hoped that it will also encourage new and different approaches in this field in the future that can capitalize on the expected improvements in the field of public corporate disclosures.

Supplementary Materials: To perform the analyses described in this paper, it was necessary to gain a detailed understanding of platinum production processes and uses. To support the attainment of this understanding, detailed maps of (i) platinum production processes; and (ii) platinum uses were constructed by gathering information from various sources [68–77]. These maps are included as supplementary materials for reference by others aiming to do research focused on the platinum industry. The map of the platinum production processes is presented in Figure S1: Platinum production processes; and the map of the platinum uses in Figure S2: Platinum uses. Furthermore, towards more complete disclosure and to support reproducibility, a third supplementary file (S3) provides concise reasons for every GRI G4 indicator excluded from the proposed framework. These supplementary files are available online at www.mdpi.com/2071-1050/10/3/878/s1.

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Author Contributions: Wouter Bam and Johan du Plessis jointly conceived and designed this investigation. Johan du Plessis performed the literature review, design and testing of the framework and the writing of the first draft of the article. Wouter Bam served as the project leader and provided input and guidance throughout all the aforementioned stages. Wouter Bam and Johan du Plessis jointly edited and finalized the article.

Conflicts of Interest: The authors declare no conflict of interest. The contributing sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A

Table A1. Relevant research work on sustainability assessment.

Study	Level of Assessment	Target Industry	TBL Dimensions Addressed	Aggregation of Indicators	Objective
Labuschagne et al. [78]	Project-level	Process industry	All	None	Assess sustainability of business operations.
Chee Tahir and Darton [79]	Organization-level	None	Organization-specific dimensions with high impact.	None	Present a method for assessing the sustainability of a business operation.
Krajnc and Glavic [80]	Organization-level	None	All (predominantly environmental).	None	Propose a list of indicators to assess the sustainability level of a company.
Singh et al. [52]	Organization-level	Steel industry	All	5-point rating system and Z score method [81]	Present a method for development of a composite sustainability performance index that measures the sustainability performance of an organisation.
Long et al. [82]	Organization-level	Iron & steel industry	All	Linear aggregation (using AHP to establish indicator weights).	Propose a sustainable assessment system specifically designed for Chinese iron and steel firms.
Salvado et al. [83]	Organization-level Supply chain-level	Automotive industry	All	Linear aggregation (using AHP to establish indicator weights).	Propose a sustainability index that provides companies with information about their TBL sustainability, at both individual and supply chain level.
Ghadimi et al. [84]	Product-level	Automotive components manufacturing industry	All	Linear aggregation of fuzzy input data (using fuzzy AHP to establish indicator weights).	Propose a weighted fuzzy assessment method for product sustainability assessment.
Study	Level of assessment	Target industry	TBL dimensions addressed	Aggregation of indicators	Objective
Winroth et al. [85]	Factory-level	None	All	None	Identify a list of performance indicators relevant for a production manager.
Garbie [86]	Organisation-level	Manufacturing industry	All	Linear aggregation (using AHP to establish indicator weights).	Modelling the required components and the introduction of a new assessment framework for assessing sustainability.
Vinodh et al. [87]	Organisation-level	Manufacturing industry	All	Linear aggregation	Propose a fuzzy-logic-based sustainability evaluation decision sup- port system for manufacturing organizations.
Lodhia and Martin [88]	Organisation-level	Mining industry	All (using integrated indicators)	None	Propose corporate sustainability indicators for a major Australian diversified resources company and engaged with expert stakeholders in determining the indicators' value and explanatory capacity.
Chen et al. [36]	Factory-level	Manufacturing industry	N/A	N/A	Present a review and evaluation study of existing assessment tools for factory sustainability assessment to clarify the difference between these tools.

Table A2. Summary of the steps in Phase 2 of the development of the framework (with notable literature sources for each step).

Step	Description	Methods Used in Literature	Literature Sources
Selection of basis for framework	Selection of an existing reporting framework to serve as basis from which selected indicators can be used in the present framework	Specific to every project.	
Setting criteria for indicator selection	Setting appropriate criteria that have to be met by all indicators to be included in the framework.	Specific to every project.	
Selection of indicators	Selection of aspects to be quantified. Selection of appropriate indicator(s) to measure each aspect.	Data-driven approach Theory-driven approach Policy-driven approach	Zhou et al. [33] OECD and European Commission [35] Niemeijer [53]
Setting indicator scope, judging indicator impact and grouping	Setting scope of what aspects are included in each indicator. Establish whether each indicators measure a positive or negative impact. Structure indicators according to sub-groups of phenomenon (if applicable).	Specific to every project.	Zhou et al. [33] OECD and European Commission [35]
Aggregation of indicators Weighting of indicators	Assign weights to indicators to account for the relative importance of the aspects measured.	Equal weighting Statistical methods (using statistical analysis of large datasets, including principal components analysis, factor analysis, data envelopment analysis, the benefit of the doubt approach and unobserved components models). Participatory methods (making use of expert knowledge by consultation of industry experts, including the budget allocation process, analytic hierarchy process and conjoint analysis).	Brandi et al. [30] OECD and European Commission [35]
Normalization of indicators	Normalize indicators to allow aggregation of indicators measured in different units.	Ranking Min-max Distance to a reference Percentage of annual differences	Krajnc and Glavič [31] OECD and European Commission [35] Sikdar et al. [32] Zhou et al. [33]
Aggregation of indicators	Aggregate indicators into one index or a few indices.	Linear aggregation Geometric aggregation Non-compensatory multi-criteria (NCMC) aggregation	Munda and Nardo [58] OECD and European Commission [35] Zhou et al. [33]
Validation by expert review	Collection of feedback from knowledgeable people on the selected indicators and the structure of the framework.	Delphi Method Interview and/or questionnaire	Geist [89] Flick [90]

Appendix B

Table A3. Indicators and sub-indicators used in the framework, including weights and case study 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
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
Environmental indicators (continued)								
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 A3. *Cont.*

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**	**1/12**	**1/12**
Social indicators (continued)								
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
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
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

Appendix C

Table A4. Sustainable development goals (SDGs) addressed by the respective indicators in the proposed framework.

Indicator	SDGs Addressed	Indicator	SDGs Addressed	Indicator	SDGs Addressed
Economic indicators		*Economic indicators*		*Social indicators*	
Econ-1	2,5,7,8,9	Envi-1	6,8,12	Soci-1	5,8
Econ-2	13	Envi-2	7,8,12,13	Soci-2	3,8
Econ-3	1,2,3,8,10,17	Envi-3	3,12,13,14,15	Soci-3	4,5,8
Econ-4	12	Envi-4	3,6,12,14	Soci-4	5,8,16
Econ-5	8	Envi-5	8,12	Soci-5	1,2,16
Econ-6	9	Envi-6	None	Soci-6	None

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