# Sustainable Life Cycle Management: Development of social indicators for technology management in the process industry of South Africa

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**Abstract**

Corporations are increasingly pressurised to commit to and report on the overall sustainability performances of operational initiatives, i.e. undertaken projects or technological innovations. A prerequisite for aligning these operational initiatives with the principles of sustainable development is a clear understanding of the various life cycles that are involved and the interactions between these life cycles. Such a holistic Life Cycle Management (LCM) approach therefore requires an effective integration of different life cycles that are fundamental to the manufacturing sector, i.e. projects that drive internal change, assets (or technologies) that are required to manufacture products or supply services, and products (or services) from which income is derived. From a technology management perspective, tools are necessary to evaluate the sustainability of these integrated life cycles. Social indicators are

subsequently introduced to evaluate the sustainability of operational initiatives in the process industry through an integrated Life Cycle Management (LCM) approach. The indicators consider the social footprint in a specific region where a process technology will be deployed in order to evaluate its potential social impacts. However, the practicability of these indicators is highly dependent on the availability of information where a technology is assessed. A case study in the South African process industry is used to demonstrate the calculation procedure. Further case studies are required in order to refine social indicators that are practical for technology management purposes in the process industry.

## 1. Introduction

The World Commission on Environment and Development officially defined the term “sustainable development” in 1987 [1]. Since then the concept has shaped the political, economic and social environment in which all businesses operate [2]. However, the concept of sustainable development is inherently vague [3] and although it is understood intuitively it remains difficult to express in concrete, operational terms [4]. In 1992 there were already more than 70 definitions for sustainable development [5], but most agree that the concept comprises social, environmental and economic dimensions with equal importance [6]. In order to assist business, the International Institute for Sustainable Development (IISD) has defined sustainable development in business terms as: “*adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today, while protecting, sustaining and enhancing the human and natural resources that will be needed in the future*” [7].

The last decade of the twentieth century marked some significant steps that were taken to draw the social dimension of sustainable development into the open [8]. However, the inclusion of social aspects in the sustainability debate and practices has been marginal compared to the attention that the other two dimensions are receiving, especially from a business perspective [8, 9, 10]. It is believed that the state of development of indicators or measurements for social business sustainability parallels that of environmental performance about 20 years ago [11]. This is mainly due to the problematic nature of social indicators and measurements, which can be attributed to two principal reasons:

- Social issues do not have any underpinning in an objective speciality such as ecology, and
- Social issues have a much higher cultural content, and various perspectives can thus feature in one issue [12].

The aim of this paper is to propose a methodology to assess the social sustainability of operational initiatives, and specifically technology management, in the process industry. In order to do so, three questions must be answered:

- Which aspects of a technology must be assessed internally? The interaction of different life cycles from an industry perspective must be addressed.
- What must be considered and measured through such an assessment? A framework of social business sustainability criteria, relevant for technology management in industry, must be defined.
- How must these criteria be measured? Social sustainable development indicators are introduced and discussed.

## 2. Life cycle interactions

A project can be defined as a temporary undertaken that has a specific objective and a definite beginning and end, with the objective mostly related to the creation of a unique product or service [13]. If this definition of a project is taken as a departure point it is concluded that the project itself has minimal environmental, economic and social impacts. However, companies are increasingly accountable for the impacts resulting from a project as well as the effects of the project on the people, environment as well as economy, even long after the project has been completed [14]. In this context a project is viewed as the vehicle to implement a capital investment in a new or improved asset or technology. Therefore, three distinct life cycles can be distinguished for technology management purposes [13]: the project life cycle, the asset or process life cycle (the life cycle of an implemented technology), and the product life cycle. Each of these life cycles consists of various phases (see Fig. 1) [13, 15]. It must be noted that different approaches to the product life cycle have been proposed, i.e. supply chain focused and product design focused life cycles. For the purposes of this paper, the supply chain approach is chosen [13].

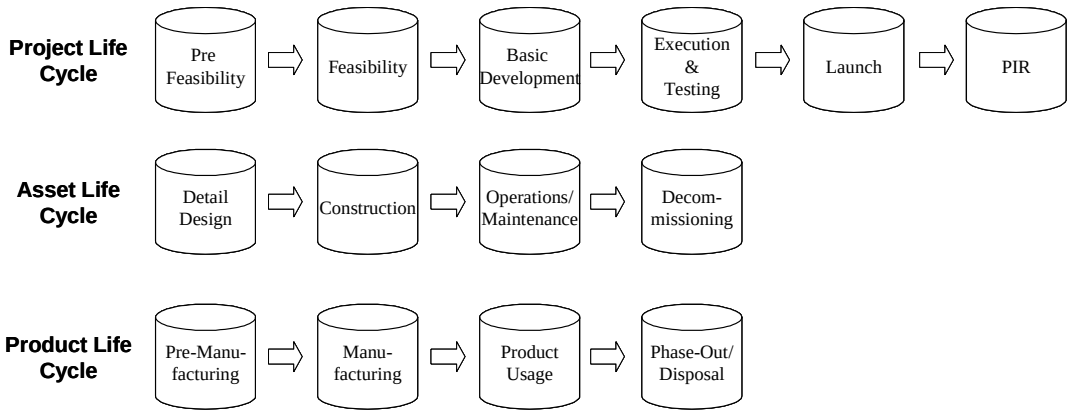


**Fig. 1. Phases of the three life cycles applicable to technology management**

It is thus the asset life cycle resulting from the project, and the subsequent product life cycle resulting from the asset, that have economic, social and environmental consequences, which are in turn associated with an implemented project. These three lifecycles do not exist in isolation but interact. In the process industry, a project normally ends after the asset commences stable operations in accordance with performance requirements [16], which marks the end of the interaction of the two life cycles (i.e. project and asset). The design phase of the asset life cycle as well as the construction phase is thus completed during the project's life cycle. The post implementation review (PIR) normally takes place during the operation phase of the asset life cycle. Furthermore, since the asset is used to manufacture the product, the product and asset life cycles also interacts, i.e. the operational phase of the asset life cycle interacts with the manufacturing phase of the product life cycle. Fig. 2 illustrates these interactions.

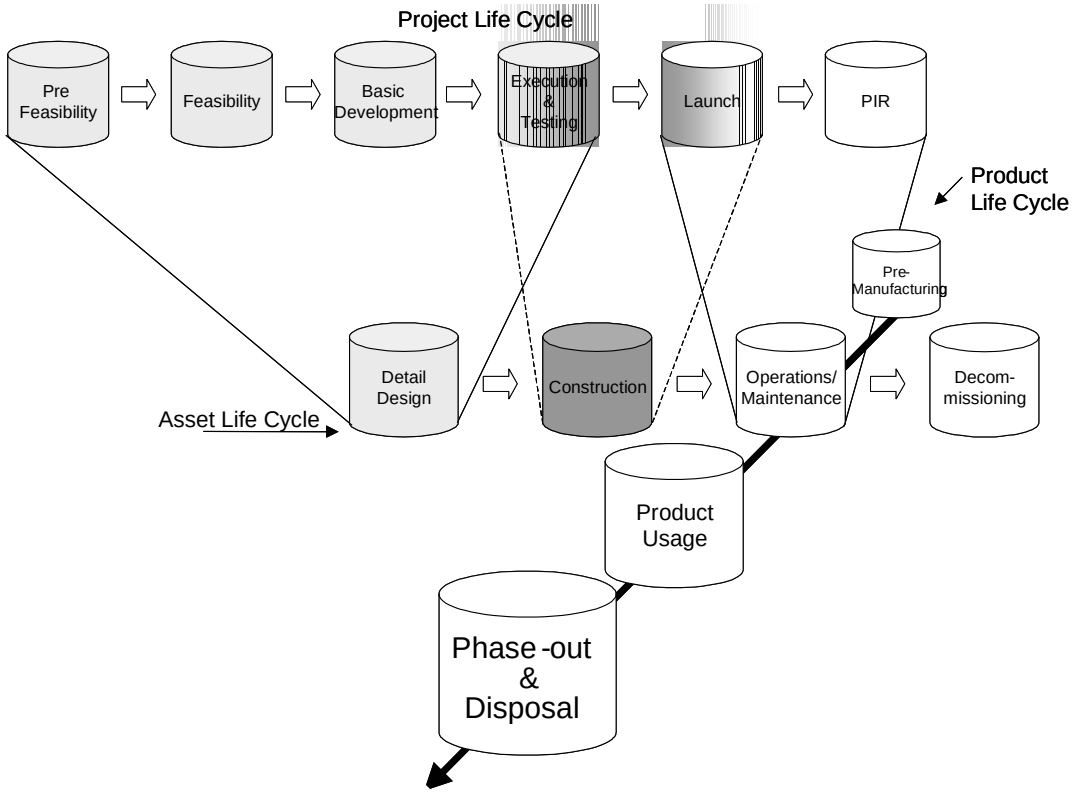


**Fig. 2. Interaction of the life cycles applicable for technology management**

Assessing the social sustainability of an operational initiative through a project therefore requires that the sustainability consequences of the total associated asset and product life cycles must be considered. Best practice would require assessing these consequences during the early phases of the project life cycle, which establishes the asset, i.e. during the pre-feasibility, feasibility and basic development phases.

## 3. Social criteria framework

A framework of social sustainability criteria, relevant for technology management purposes in the process industry, needs to be defined as a requirement for social assessments. A prerequisite for defining this framework is the clarification of the relationship between Corporate Social Investment (CSI) and Social Business Sustainability. The sustainable development assessment frameworks and the sustainability or Corporate Social Responsibility (CSR) reports that have been reviewed [17], indicate that social sustainability entails far more than only CSR projects or CSI in communities. Although companies can have a large and positive effect on society through their CSI or CSR projects [18], core business activities have a bigger social impact than the philanthropic, i.e. CSI and CSR, contributions of the company can ever have [8]. However, CSR projects and CSI do contribute to the overall sustainability of a company and should be evaluated as such [19, 20]. Although it is funded by profit generated by the operational activities it is not part of a company's core business activities, but is still guided by the company's corporate social responsibility strategy [17]. Nevertheless, a framework with the aim of evaluating the sustainability of an operational initiative should not take the CSR initiatives of the company as a whole into consideration. Therefore, a distinction is

made between operational and societal initiatives, and operational initiatives are then evaluated separately in terms of the three dimensions of sustainable development (see Fig. 3) [17].

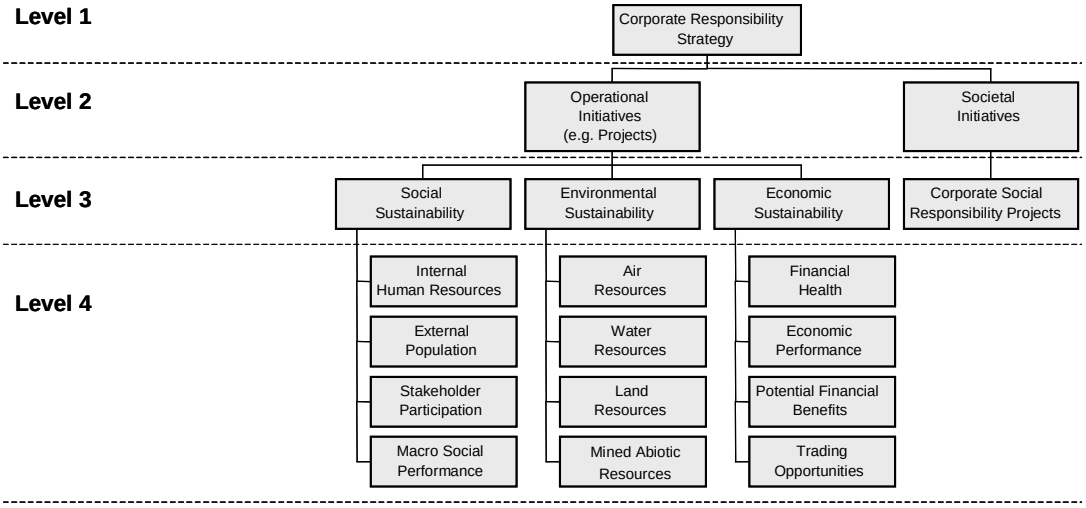


**Fig 3. Levels 1 to 4 of the proposed framework to assess the sustainability of operational initiatives [17]**

The social dimension of the framework has been further developed. Since the aim of the framework is to evaluate the social sustainability performances of operational initiatives, the social dimension of the proposed framework is concerned with the company's impacts on the social systems in which it operates, as well as the company's relationship with its various stakeholders. A definite distinction is therefore made between impacts on society and on the natural environment, which is considered in the environmental dimension of the framework and has been described elsewhere [17].

Business has a social responsibility, and thus a social impact, on three levels within society, which is a function of its role as:

- Employer;
- Leading “citizen” in the community of operation; and
- Good and concerned citizen of the country of operation [21].

Three main criteria of social business sustainability are subsequently dedicated to account for these impacts. They are: Internal Human Resources, External Population and Macro Social Performance. The fourth main criteria of social business sustainability is Stakeholder Participation (see Fig.3 and Fig. 4) due to the fact that stakeholders are involved in all three of the other criteria, and stakeholder involvement has been defined as one of the five key corporate sustainability performance principles [22]. Furthermore, stakeholder participation is regarded as a social sustainability criterion within most of the frameworks or guidelines developed with a business perspective, e.g. GRI, IChemE and the Dow Jones Sustainability Group Index [17], and thus deserves to be addressed separately. Definitions of the criteria are shown in Table 1.

The social criteria of the framework have been verified by a set of case studies [15]. For each of the three life cycle phases of assets (see section 2), i.e. construction, operation (which includes the product life cycle) and decommissioning, four case studies were chosen that aimed to determine the significant social impacts that may occur during these life cycle phases:

- The construction of four facilities in the process industry: a mine; an incinerator; and a gas pipe line across two countries.

- The operation of four chemical manufacturing facilities of which two are located in South Africa, one in Germany and one in the United States of America.
- The decommissioning of four process facilities: a cyanide manufacturing plant; a fibres manufacturing plant; a mine; and one unit within a process plant [15].

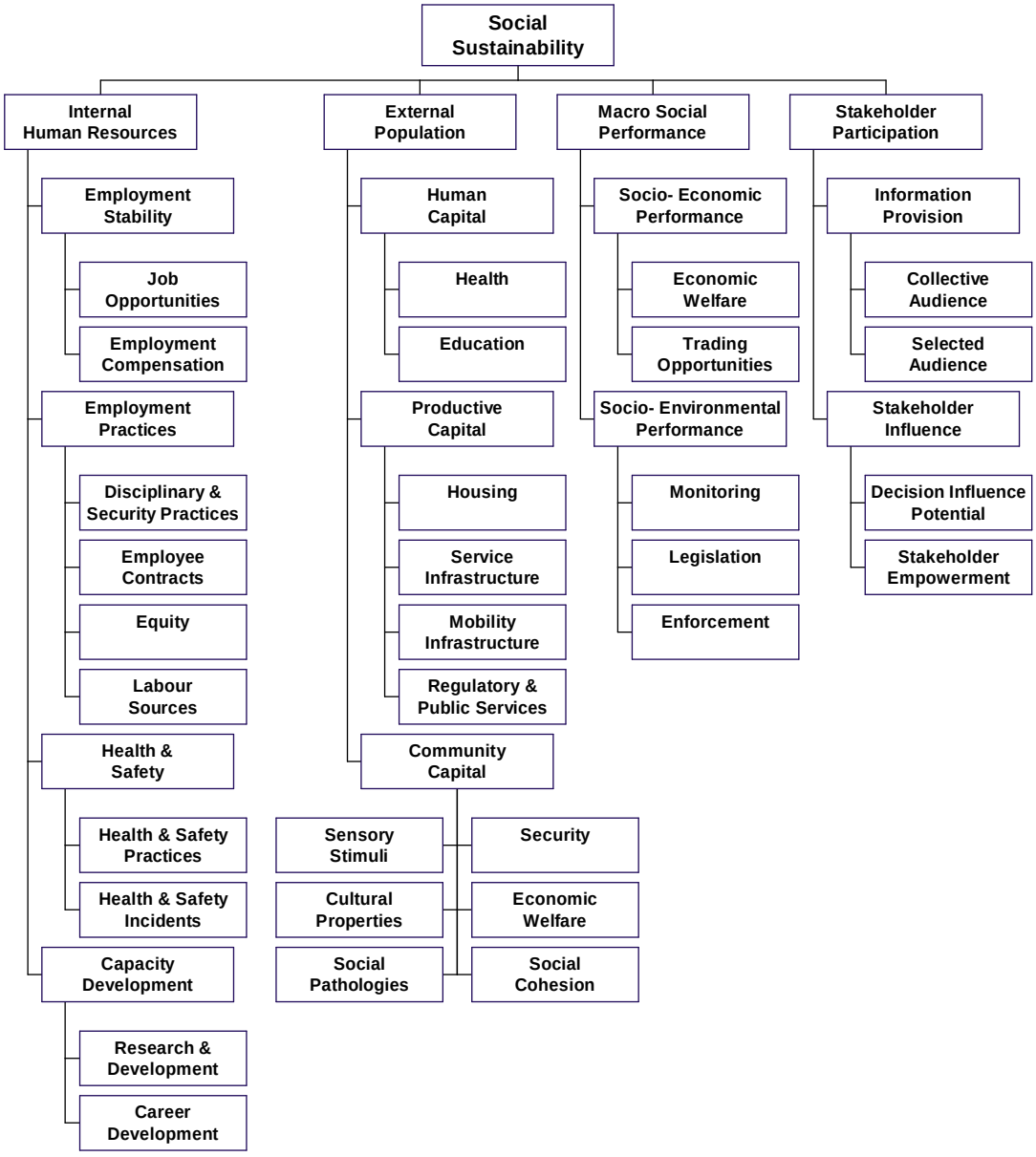


**Fig 4. Social business sustainability framework**

## Table 1. Definitions for the social criteria

| **Internal Human Resources** | **Internal Human Resources focuses on the social responsibility of the company towards its workforce and includes all aspects of employment.** |
|---|---|
| Employment Stability | The criterion addresses a business initiative's positive and negative impact on work opportunities within the company, the stability thereof as well as evaluating the fairness of compensation. |
| Employment Practices | Disciplinary and secrecy practices as well as employee contracts are addressed under this criterion. These are evaluated to ensure that the company complies with the laws of the country, international human rights declarations as well as other human rights and fair employment practice standards. |
| Health & Safety | The criterion focuses on the health and safety of the workforce and evaluates implemented preventive measures as well as the occurrence and handling of health and/or safety incidents. |
| Capacity Development | The criterion addresses two different aspects, namely research and development, and career development. With regards to research and development, the criterion assesses investments in sustainability technologies, etc. |
| **External Population** | **External Population focuses on the external impacts of the company's operational initiatives on a society, e.g. impacts on the availability of services, community cohesion, economic welfare, etc.** |
| Human Capital | Human Capital refers to an individual's ability to work in order to generate an income and encompasses aspects such as health, psychological wellbeing, education, training and skills levels. The criterion addresses Health and Education separately. |
| Productive Capital | Productive capital entails the assets and infrastructure an individual needs in order to maintain a productive life. The criterion measures the strain placed on or development of these assets and infrastructure availability by the business initiative. |
| Community Capital | This criterion takes into account the positive and negative effects of an operational initiative on the social and institutional relationships and networks of trust, reciprocity and support as well as the typical characteristics of the community. |
| **Macro Social Performance** | **Macro Social Performance focuses on the contribution of an organisation to the environmental and financial performance of a region or nation, e.g. contribution to exports.** |
| Socio-Economic Performance | This criterion addresses the external economic impact of the company's business initiatives. Economic welfare (contribution to GDP, taxes, etc.) as well as trading opportunities (contribution to foreign currency savings, etc.) are addressed separately. |
| Socio-Environmental Performance | This criterion considers the contributions of an operational initiative to the improvement of the environment for society on a community, regional and national level. The extension of the environmental monitoring abilities of society, as well as the enhancement of legislation and the enforcement thereof, are included in this criterion. |
| **Stakeholder Participation** | **Stakeholder Participation focuses on the relationships between the company and ALL its stakeholders (internal and external) by assessing the standard of information sharing and the degree of stakeholder influence on decision-making.** |
| Information Provisioning | The quantity and quality of information shared with stakeholders are measured. Information can either be shared openly with all stakeholders (Collective Audience) or shared with targeted, specific groups of stakeholders (Selected Audience). |
| Stakeholder Influence | The degree to which the company actually listens to the stakeholders' opinion should also be evaluated. Two separate sub-criteria are included: Decision Influence Potential and Stakeholder Empowerment. |

The case studies involved the evaluation of project related documentation, and the conducting of personal interviews with project responsible individuals. The case studies concluded that certain social impacts are more important in certain phases. For example, in the operation phase the main social concern is sensory stimuli, i.e. noise and odour, while employment opportunities are the major social concern in the

construction and decommissioning phases. Furthermore, it has been evident that stakeholder participation is crucial in all life cycle phases. A pre-survey has also been conducted in a South African company in the process industry to establish the suitability of the social criteria, as well as the relevance of the criteria in the framework, in terms of sustainable business practices and specifically project Life Cycle Management [23]. The case studies and pre-survey showed that the framework does include all of the relevant social criteria.

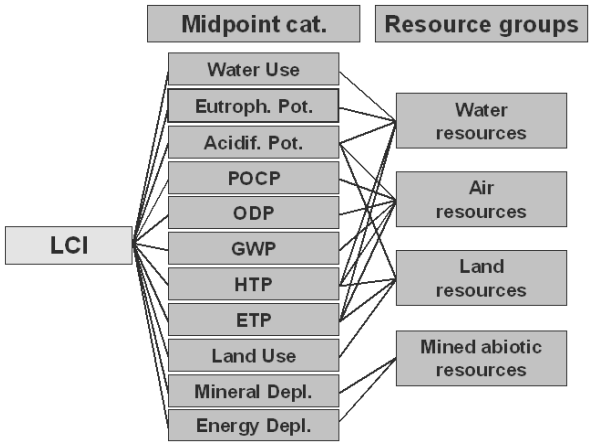


**Fig. 5. Casual relationship between environmental LCIs and the resource groups of Fig. 3**

## 4. Indicator development

The case studies used for verification of the social criteria (see section 3) have also been used to compile a list of possible social interventions, i.e. for a social Life Cycle Inventory (LCI) of assessed operational initiatives in the process industry. A Life Cycle Impact Assessment (LCIA) approach has been proposed before for the evaluation of the social impacts of life cycle systems from compiled LCIs [24, 25]. An established LCIA methodology for the four environmental resource groups, as shown

in Fig. 3, is subsequently used as basis for the development of social indicators. The environmental LCIA methodology, termed the Resource Impact Indicator (RII) approach (see Fig. 5), considers the current and target ambient state or ecological footprint through a conventional distance-to-target normalisation and weighting calculation procedure [26]. A similar calculation procedure is proposed for Social Impact Indicators (SIIs) with the four main criteria of Fig. 3 as Areas of Protection (AoP). The general calculation procedure is described through the following equation:

$$SII_G = \sum_C \sum_X Q_X \cdot C_C \cdot N_C \cdot S_C \quad \textbf{1}$$

Where: $SII_G$ = Social Impact Indicator calculated for a main social group through the summation of all impact pathways of all social interventions of an evaluated life cycle system.

$Q_X$ = Quantifiable social intervention (X) of a life cycle system in a midpoint impact category C.

$C_C$ = Characterisation factor for an impact category (of intervention X) within the pathway. As a first approximation no characterisation factors are assumed and social LCI interventions are considered separately.

$N_C$ = Normalisation factor for the impact category based on the social objectives in the region of assessment, i.e. the inverse of the target state of the impact category.

And; $S_C = \frac{C_S}{T_S} =$ Significance (or relative importance) of the impact category in a social group based on the distance-to-target method, i.e. current social state divided by the target social state.

In order to follow the calculation procedure, midpoint categories had to be established. For this purpose, the compiled list of social interventions was mapped against the social criteria at various levels within the framework (see Fig. 4). A casual relationship diagram was consequently established (see Appendix A) whereby midpoint categories were defined. Three measurement methods are proposed to express the defined midpoint categories in equivalence units (see Table 2):

- Established risk assessment approaches, which require a subjective evaluation of the probability of occurrence, the projected frequency of the occurrence, and the potential intensity thereof;
- Quantitative evaluation approaches, including, but not limited to, costs and direct measurements in society; and
- Qualitative evaluation approaches, which require appropriate subjective scales and associated guidelines, and have been proposed for the industrial ecology and streamlined LCA disciplines [15].

From the definition of the midpoint categories it is evident that the normalisation and significance steps will be constraint by what is practicably measurable within a society where an operational initiative (from an industry perspective) will typically occur. In this regard the availability of information will most definitely differ between developed and developing countries. Furthermore, the projection of the social interventions of a project or technology may be problematic or at least differ from case to case.

**Table 2. Midpoint categories and evaluation methods**

| Social Impact Indicators (SIIs) | Midpoint category | Measurement methods to establish equivalence units |
|---|---|---|
| **Internal Human Resources** | Permanent internal employment positions | Quantitative |
| | Internal Health and Safety situation | Risk |
| | Knowledge level / Career development | Quantitative |
| | Internal Research and Development capacity | Quantitative |
| **External Population** | Comfort level / Nuisance | Risk |
| | Perceived aesthetics | Qualitative |
| | Local employment | Quantitative |
| | Local population migration | Qualitative |
| | Access to health facilities | Quantitative[a] |
| | Access to education | Quantitative[a] |
| | Availability of acceptable housing | Quantitative[a] |
| | Availability of water services | Quantitative[a] |
| | Availability of energy services | Quantitative[a] |
| | Availability of waste services | Quantitative[a] |
| | Pressure on public transport services | Quantitative |
| | Pressure on the transport network / People and goods movement | Quantitative |
| | Access to regulatory and public services | Quantitative |
| **Stakeholder Participation** | Change in relationships with stakeholders | Qualitative |
| **Macro-Social Performance** | External value of purchases / supply chain value/Nature of Purchases | Quantitative |
| | Migration of clients / Changes in the product value chain/Nature of Sales | Qualitative/Quantitative |
| | Improvement of socio-environmental services | Quantitative |

a Actual performance ranges.

## 5. Case study example

In June 2002 a decision was taken to decommission a chemical production plant in South Africa. This decision was an economic-based decision due to a declining market for the end product. The main customer of the plant and its product announced that it would stop operations in December 2004 and a decision was

subsequently made to decommission the plant and complete rehabilitation by June 2004 [27]. This specific case is used to demonstrate the calculation method.

**Table 3: Case study information availability with regards to social interventions**

| Intervention | Project Information Available | Social Footprint Information Available |
|---|---|---|
| Nature of Jobs | 140 employment opportunities have been lost. | Unemployment Percentage (Local Employment):<br>Current: 25% of employable population<br>Target: Not clearly defined; for calculation purposes set at 15%<br>Number of Employed Personnel (Permanent Positions):<br>Current: 76668<br>Target: 105301 (based on a reduction of 15% in unemployment) |
| Wages | Not available | |
| Employee Benefits | Not available | |
| Health & Safety Incidents | Not available | |
| Investment in R&D facilities | Not Applicable | |
| Investment in Training | Not available | |
| Migratory Influx | Not available | |
| Investment in Health Facilities | Not available | |
| National Taxes | Not available | |
| Local Taxes | Not available | |
| Investment in Education | Not available | |
| Investment in Housing | Not available | |
| Investment in Water Services | Not available | |
| Water Usage | 200 $m^3$ per month | Not available |
| Investment in Energy Services | Not available | |
| Energy Usage | 861 MWh per month | Energy Usage of the local municipality:<br>Current: 47950 MWh<br>Target: No target set, thus equal to current |
| Waste Generated | Not available | |
| Investment in Waste Services | Not available | |
| Investment in Regulatory & Public Services | Not available | |
| Investment in Transport Network | Not available | |
| Transport of People | Not available | |
| Transport of Goods | Not available | |
| Indirect Employment Opportunities | Not available | |
| Structure/Location | Not available | |
| Noise | Not available | |
| Odour | Not available | |
| Nature of Purchases | Not available | |
| Nature of Sales | R150 million annual turnover | Gross Domestic Product of Province:<br>Current: R77 835 million<br>Target: No target set, thus equal to current |
| Investment in Socio-Environmental Services | Not available | |
| Investment in Stakeholder Participation Initiatives | Not available | |

Table 3 shows the list of interventions and indicates whether information with regards to the interventions was available for the project itself and for the region (to determine the social footprint). Social footprint information was only considered where project specific information was available. The available information was used to calculate values for the Social Impact Indicators as far as possible (see Table 4), using equation 1.

**Table 4: Calculated Social Impact Indicators from the available case study intervention information**

| Area of Protection | Intervention[a] | Normalisation value ($T_S^{-1}$) | Significance value ($C_S/T_S$) | Midpoint indicator value[a] | SII value |
|---|---|---|---|---|---|
| **Internal Human Resources** | **Nature of jobs** | $9.50\times10^{-6}$ | **0.728** | $-9.68\times10^{-4}$ | $-9.68\times10^{-4}$ |
| **External Population** | **Nature of jobs** | $3.49\times10^{-5}$ | **1.667** | $-8.15\times10^{-3}$ | $9.81\times10^{-3}$ |
| | **Energy usage** | $2.09\times10^{-5}$ | **1.0** | $1.80\times10^{-2}$ | |
| **Macro Social Performance** | **Nature of sales** | $1.28\times10^{-5}$ | **1.0** | $-1.93\times10^{-3}$ | $-1.93\times10^{-3}$ |
| **Stakeholder Participation** | | | | | **Not available** |

a Refer to Appendix A for the relationships between interventions and midpoint categories in the pathway of the main SII groups.

The calculated SIIs highlight the negative influence of the undertaken project with regards to the loss of jobs (Internal Human Resources and External Population category groups) and the loss of sales in the local region associated with the departure of a customer or client from the region (Macro Social Performance category group). However, the closure of the plant reduces the burden on the local electricity infrastructure significantly, which indicates a positive overall social impact

of the project on the External Population category group. A final conclusion as to the overall positive or negative social impact of the case study, based on the limited available information, is dependent on subjective weighting values for the four main social groups, but an equal weighting would point towards an overall positive social influence of the undertaken project.

## 6. Conclusions

A calculation procedure has been introduced in order to calculate Social Impact Indicators (SIIs) for evaluated technology systems in the process industry. The calculation procedure follows a conventional Life Cycle Impact Assessment (LCIA) approach, and specifically a distance-to-target methodology whereby the social footprint is considered in the region where an operational initiative is to be implemented. However, although the calculation procedure has been demonstrated through a case study, many of the defined midpoint categories for the approach show certain limitations in terms of the practicability of their use in the process industry. Further case studies are therefore required in order to:

- Identify the kind of information that is typically available at the point of assessing the sustainability performance of specific operational initiatives in the early life cycles stages of projects in the process industry.
- Refine and establish the SII scientific methodology to translate the available operational initiative information for sustainability performance assessments.
- Demonstrate the incorporation of the SII approach together with LCA and LCC results for internal decision-making.

Also, subjective weighting values, based on the judgements of company-specific decision-makers in the process industry, is required for the four main social category groups, in order to establish the overall social performance of evaluated operational initiatives.

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## 8. Appendix A

The causal relationship map has been broken down into 7 diagrams. Four diagrams are used to show the causal relationship diagram for the External Population area of protection while the causal relationships for the other areas of protection are shown in separate diagrams.

### 8.1. Internal Human Resources (IHR)

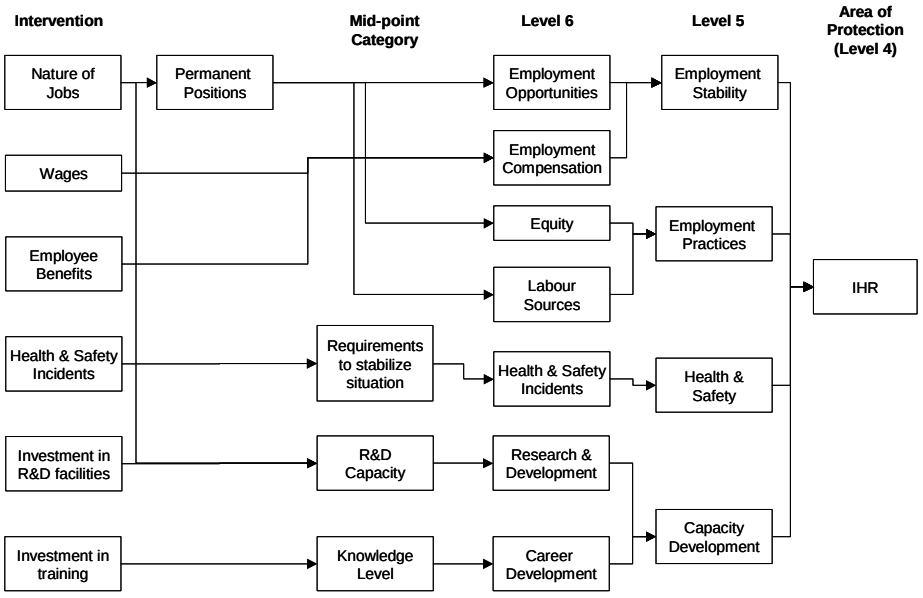


**Fig 6. Causal Relationships Map for Internal Human Resources**

## 8.2. External Population (EP)

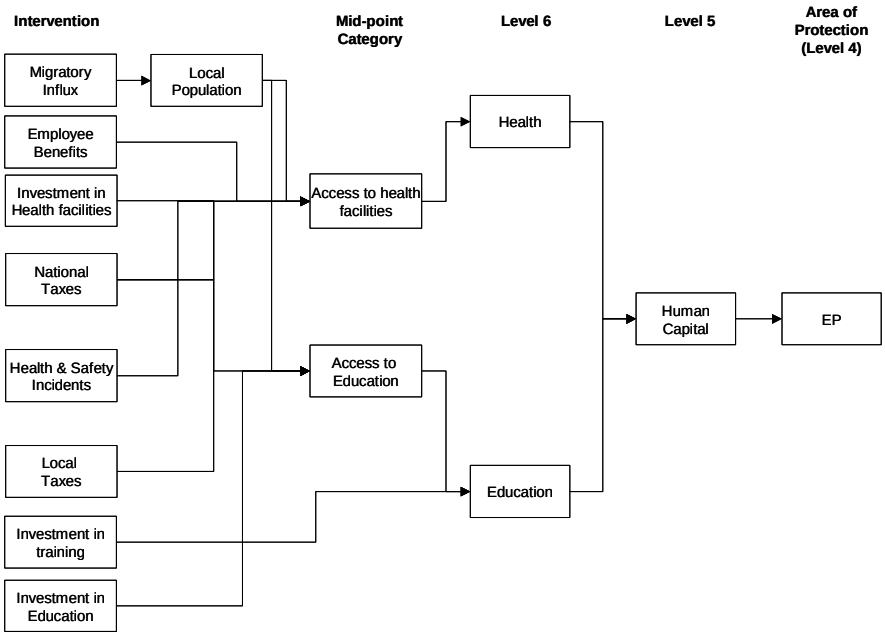


**Fig 7. Causal Relationship Map for External Population: Human Capital**

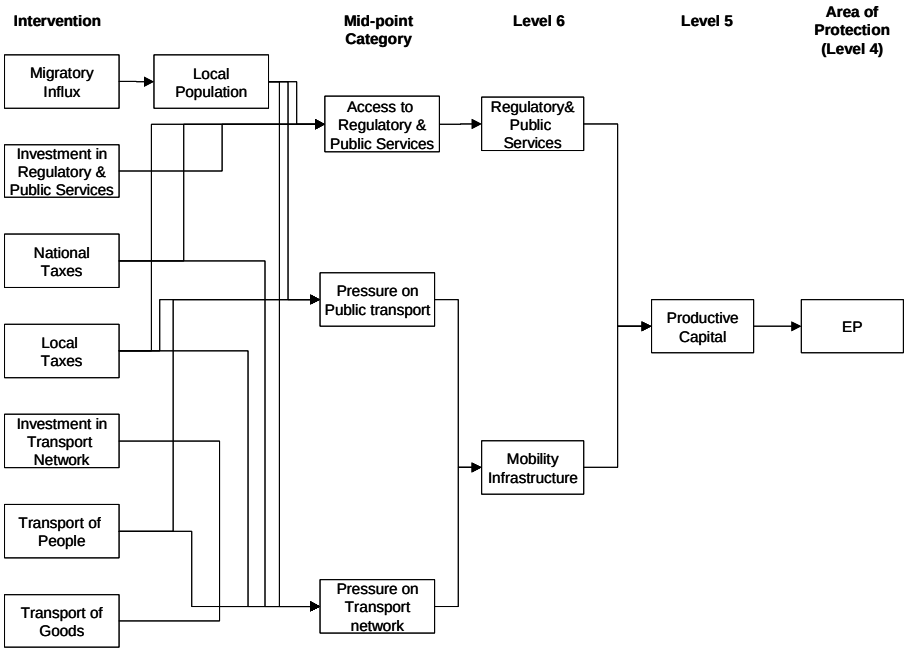


**Fig 8. Causal Relationship Map for External Population: Productive Capital (1)**

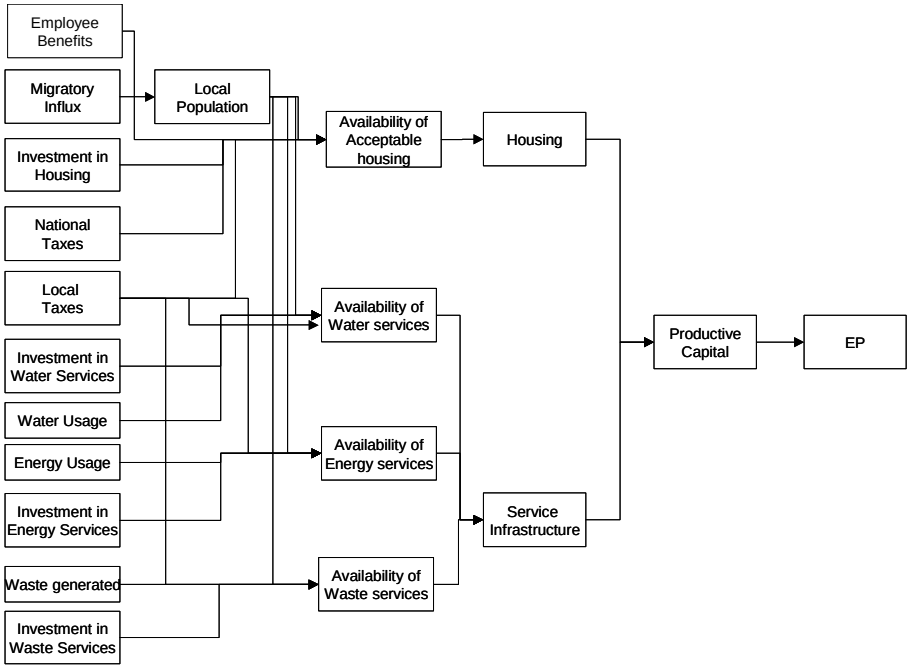


**Fig 9. Causal Relationship Map for External Population: Productive Capital (2)**

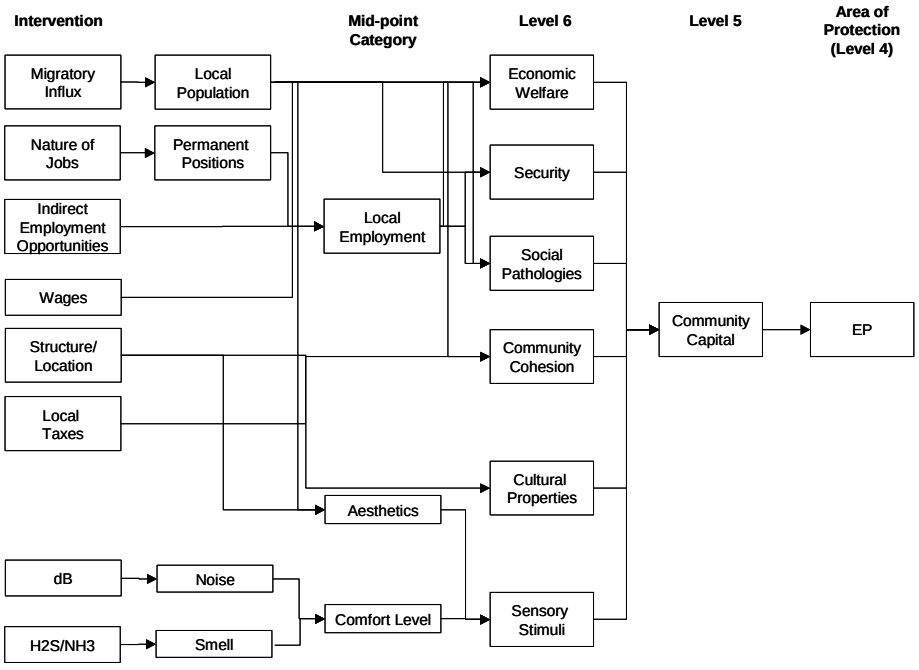


**Fig 10. Causal Relationship Map for External Population: Community Capital**

## 8.3. Macro Social Performance (MSP)

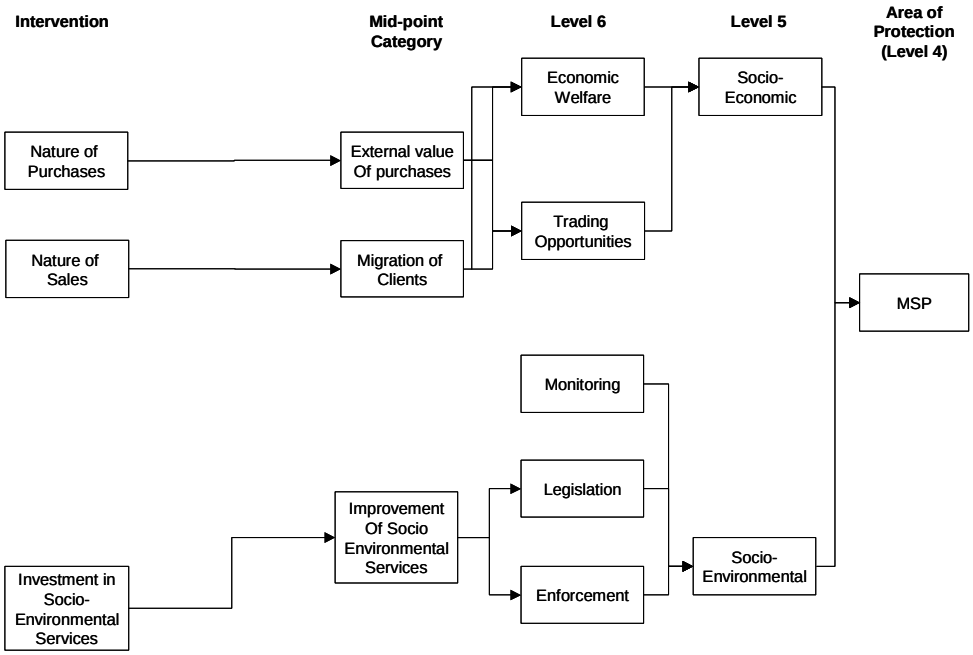


**Fig 11. Causal Relationship Map for Macro Social Performance**

## 8.4. Stakeholder Participation

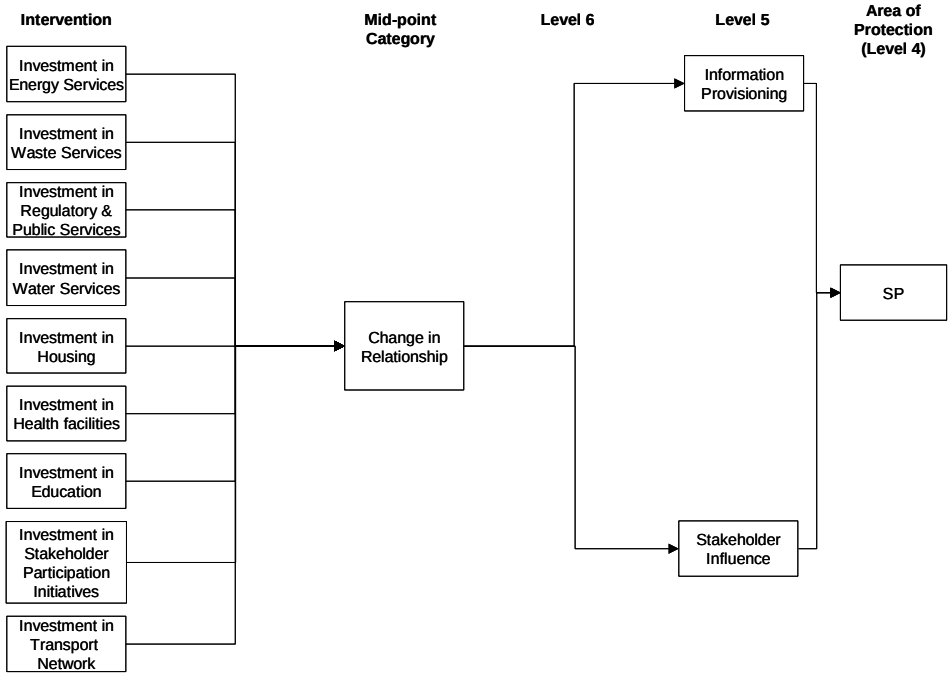


**Fig 12. Causal Relationship Map for Stakeholder Participation**