

# **SUSTAINABLE LIFE CYCLE MANAGEMENT: A CASE STUDY IN THE PROCESS INDUSTRY TO DEVELOP A CALCULATION PROCEDURE FOR SOCIAL INDICATORS FOLLOWING CONVENTIONAL LCIA METHODS**

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## **SUMMARY**

**Social criteria have been proposed to evaluate the sustainability of operational initiatives in the process industry through an integrated Life Cycle Management (LCM) approach. Indicators for these social criteria are subsequently introduced. The calculation of the indicators follows conventional LCIA methods, and specifically the distance-to-target approach for normalisation, whereby a societal footprint is used to establish the significance of social impacts. However, the practicability of these indicators is highly dependent on the availability of information where an operational initiative 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 the social criteria, and indicators, that are practical for management purposes in the process industry.**

**Keywords: social criteria; indicators; life cycle impact assessment**

## **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:

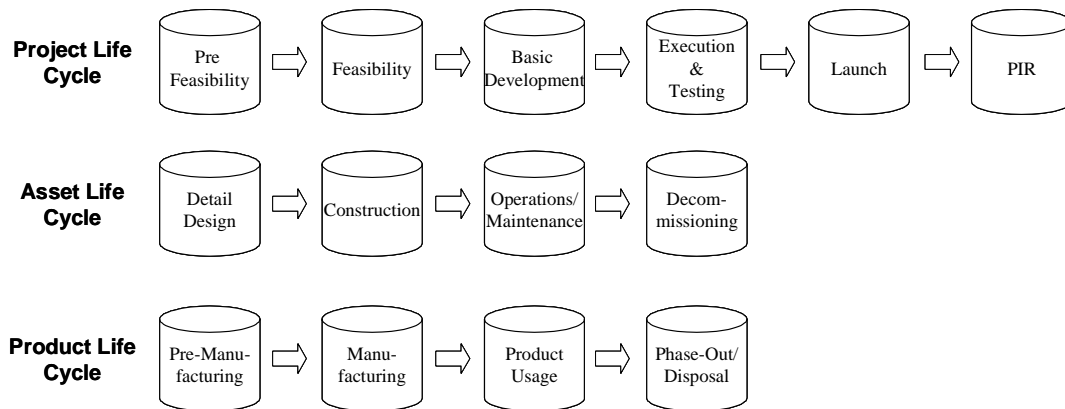
- Social issues do not have any underpinning in an objective speciality such as ecology, and
- Social issues have a much higher cultural content, and various perspectives can thus feature in one issue [12].

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

- Which aspects of a technology or project 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 operational initiatives in industry, must be defined.
- How must these criteria be measured? Social sustainable development indicators are introduced and discussed.

## 2. LIFE CYCLE INTERACTIONS

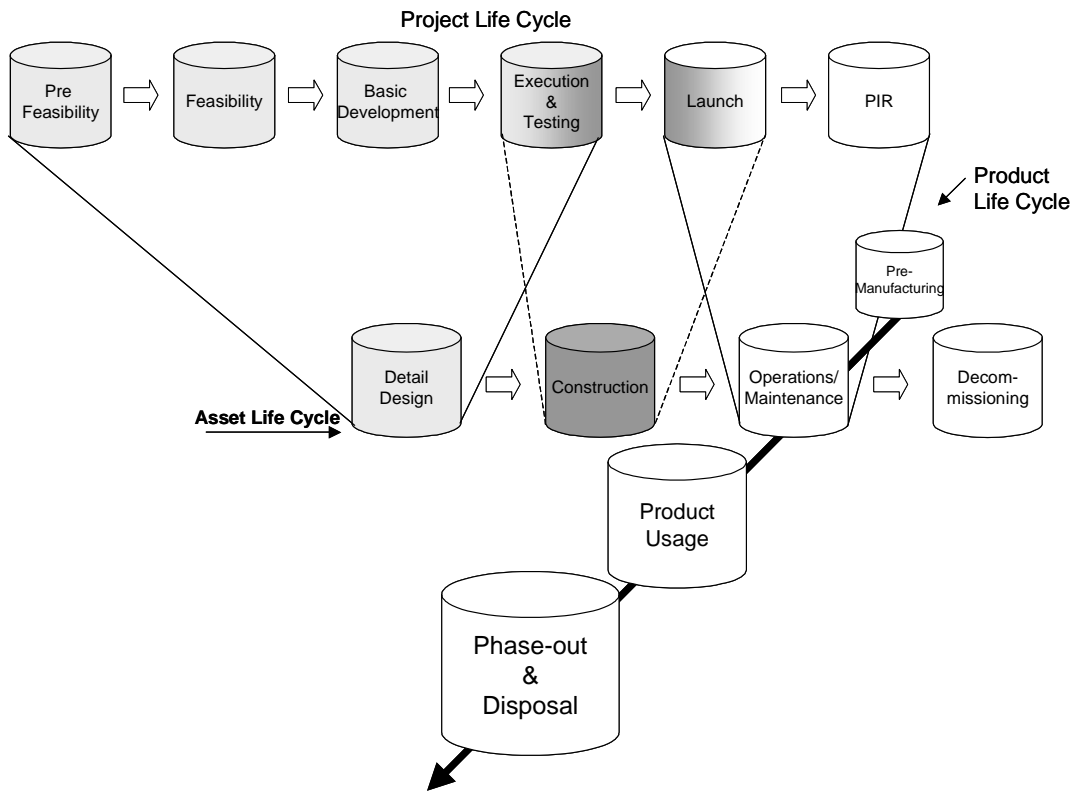
A prerequisite for assessing the social sustainability of operational initiatives, such as undertaken projects or technological innovations, is a clear understanding of the various life cycles that are involved and the interactions between these life cycles [13]. In industry, three distinct life cycles can be distinguished between [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) [14].



**Fig 1. Phases of the three life cycles**

In this context a project is viewed as the vehicle to implement a capital investment in a new or improved asset or technology. Therefore, the project and asset life cycles interact. The project normally ends after the asset commences stable operations in accordance with performance requirements [15]. 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.

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. Assessing the social sustainability of an operational initiative therefore requires that the sustainability consequences of these 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.



**Fig 2. Interactions between the three life cycles**

### 3. SOCIAL CRITERIA FRAMEWORK

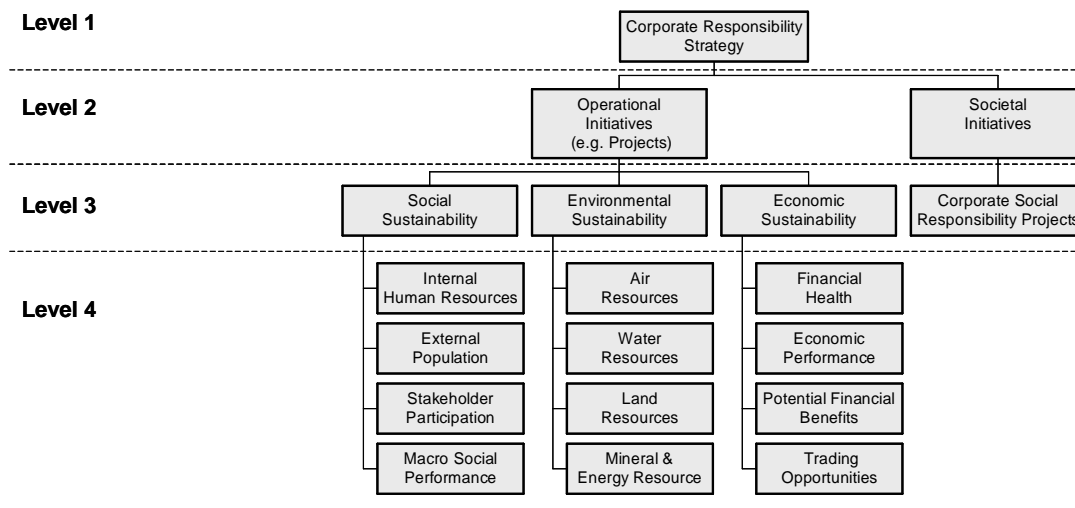
A framework of social sustainability criteria, relevant for operational initiatives in industry, needs to be defined as a requirement for social assessments. A prerequisite for defining this framework is the clarification of the relationship between Corporate Social Investment and Social Business Sustainability. The sustainable development assessment frameworks and the sustainability or corporate social responsibility (CSR) reports that have been reviewed [16], indicate that social sustainability entails far more than only CSR projects or corporate social investment (CSI) in communities. Although companies can have a large and positive effect on society through their CSI or CSR projects [17], 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 [18, 19]. Yet, 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 [16]. 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) [16].

The social dimension of the framework has been further developed. Since the aim with 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. 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 [20].



**Fig 3. Levels 1 to 4 of the proposed framework to assess the sustainability of operational initiatives [16]**

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. Since stakeholders are involved in all three of these criteria, and stakeholder involvement has been defined as one of the five key corporate sustainability performance principles [21], and 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, the fourth main criteria of social business sustainability is Stakeholder Participation (see Fig.3 and Fig. 4) [16]. Definitions of the criteria are shown in Table 1.

The social criteria of the framework were verified by a set of case studies [14]. 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; petrol filling stations; 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 [14].

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 [22]. The case studies and pre-survey showed that the framework does include all of the relevant social criteria.

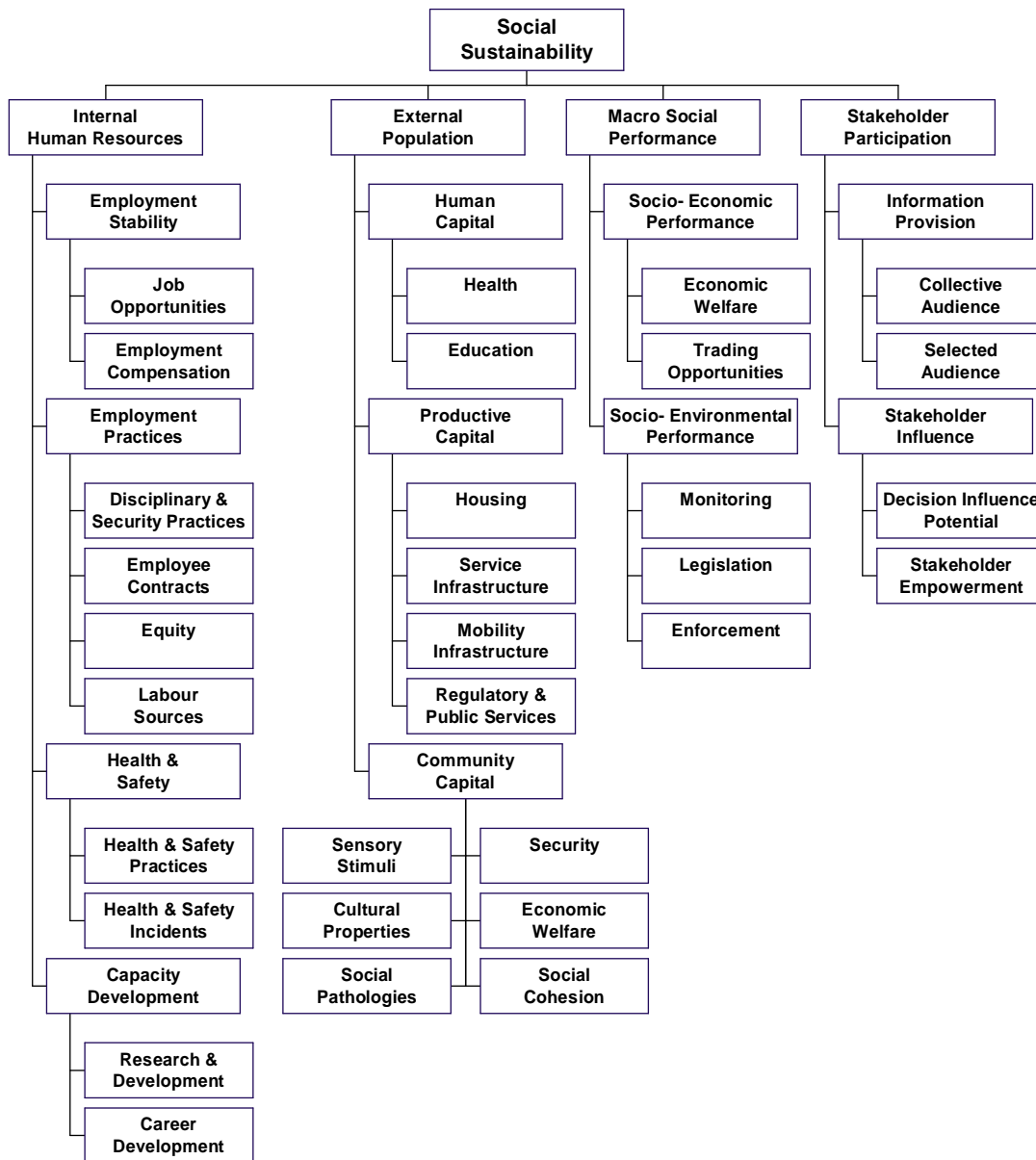


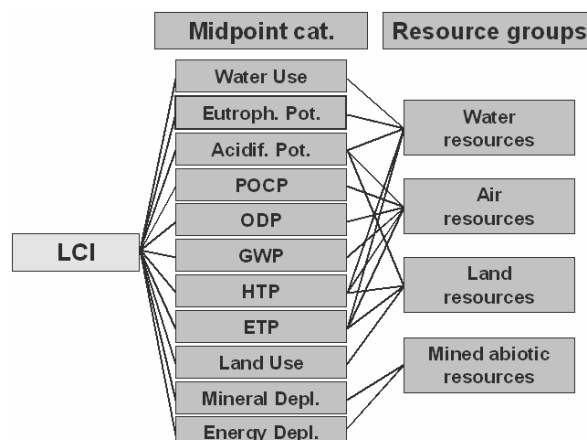
Fig 4. Social Business Sustainability framework

<b>Internal Human Resources</b>	<b>Internal Human Resources focuses on the social responsibility of the company towards its workforce and includes all aspects of employment.</b>
Employment Stability	The criterion addresses a business initiative's 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 it 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 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.
<b>External Population</b>	<b>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.</b>
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 these assets and infrastructure availability by the business initiative.
Community Capital	This criterion takes into account the effect 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.
<b>Macro Social Performance</b>	<b>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.</b>
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.
<b>Stakeholder Participation</b>	<b>Stakeholder Participation focuses on the relationships between the company and ALL its stakeholders (internally and externally) by assessing the standard of information sharing and the degree of stakeholder influence on decision-making.</b>
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.

**Table 1. Definitions for the social criteria**

#### 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 [23, 24]. An established LCIA methodology 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 [25].



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

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:

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

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.

Social Impact Indicators (SIIs)	Midpoint category	Measurement methods to establish equivalence units
<b>Internal Human Resources</b>	Permanent internal employment positions	Quantitative
	Internal Health and Safety situation	Risk
	Knowledge level / Career development	Quantitative
	Internal Research and Development capacity	Quantitative
<b>External Population</b>	Comfort level / Nuisances	Risk
	Perceived aesthetics	Qualitative
	Local employment	Quantitative
	Local population migration	Qualitative
	Access to health facilities	Quantitative
	Access to education	Quantitative
	Availability of acceptable housing	Quantitative
	Availability of water services	Quantitative
	Availability of energy services	Quantitative
	Availability of waste services	Quantitative
	Pressure on public transport services	Quantitative
	Pressure on the transport network / People and goods movement	Quantitative
Access to regulatory and public services	Quantitative	
<b>Stakeholder Participation</b>	Change in relationships with stakeholders	Qualitative
<b>Macro-Social Performance</b>	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

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

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 [14].

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.

Intervention	Project Information Available	Social Footprint Information Available
Nature of Jobs	140 employment opportunities have been lost.	Unemployment Percentage (Local Employment): Current: 25% of employable population Target: Not clearly defined; for calculation purposes set at 15% Number of Employed Personnel (Permanent Positions): Current: 76668 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 <sup>3</sup> per month	Not available
Investment in Energy Services	Not available	
Energy Usage	861 MWh per month	Energy Usage of Emalahleni Municipality: Current: 47950 MWh 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	R10 million annual turnover	Gross Domestic Product of Province: Current: R77 835 million Target: No target set, thus equal to current
Investment in Socio-Environmental Services	Not available	
Investment in Stakeholder Participation Initiatives	Not available	

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



## 5. EXAMPLE

In June 2002 a decision was taken to decommission a cyanide production plant in the Mpumalanga Province of South Africa. This decision was an economic-based decision due to a declining market for the end product. The main customer of the plant announced that it would stop operations in December 2004 and the plant decided that decommissioning and rehabilitation had to be completed by June 2004 [26]. This specific case is used to demonstrate the calculation method.

Table 3 shows the list of interventions and indicates whether information with regards to the interventions were 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.

Area of Protection	Intervention <sup>a</sup>	Normalisation value ( $T_S^{-1}$ )	Significance value ( $C_S/T_S$ )	Midpoint indicator value <sup>a</sup>	SII value
Internal Human Resources	Nature of jobs	$9.50 \times 10^{-6}$	0.728	$-9.68 \times 10^{-4}$	$-9.68 \times 10^{-4}$
External Population	Nature of jobs	$3.49 \times 10^{-5}$	1.667	$-8.15 \times 10^{-3}$	$9.81 \times 10^{-3}$
	Energy usage	$2.09 \times 10^{-5}$	1.0	$1.80 \times 10^{-2}$	
Macro Social Performance	Nature of sales	$1.28 \times 10^{-5}$	1.0	$-1.28 \times 10^{-4}$	$-1.28 \times 10^{-4}$
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.

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

The calculated SIIs highlight the negative influence of the undertaken project with regards to the losses 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 of the region (Macro Social Performance category group). However, the closer 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 systems such as operational initiatives 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 performances 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 namely. 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)

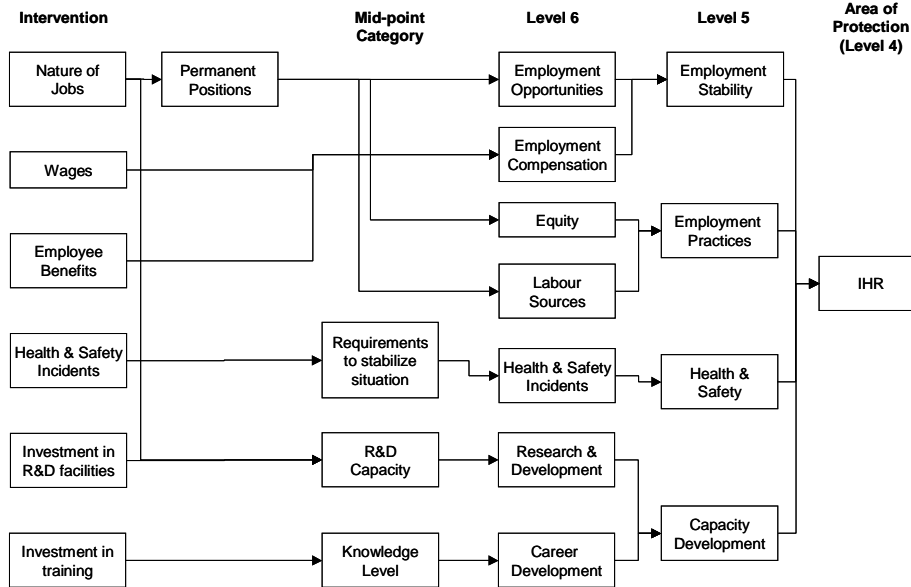


Fig 6. Causal Relationships Map for Internal Human Resources

### 8.2 External Population (EP)

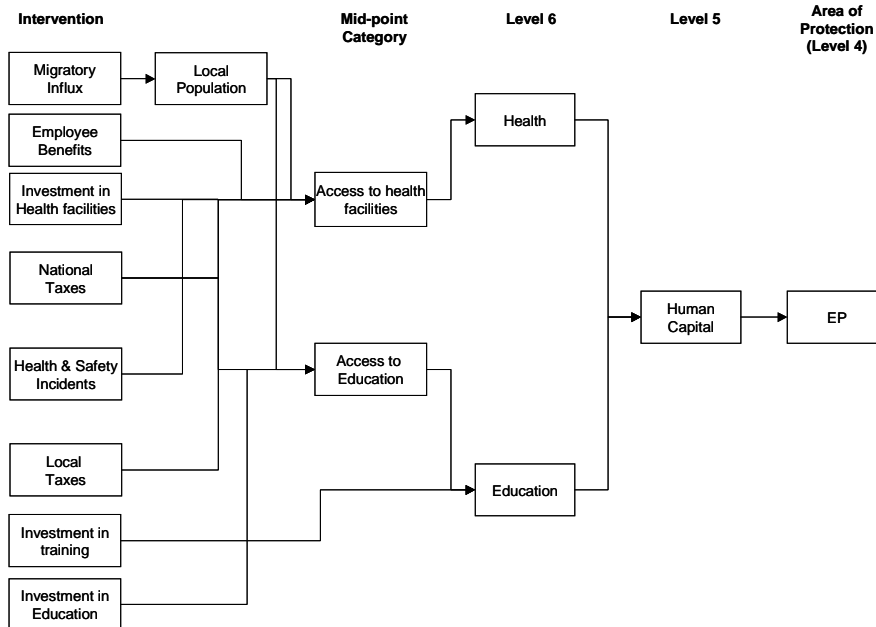
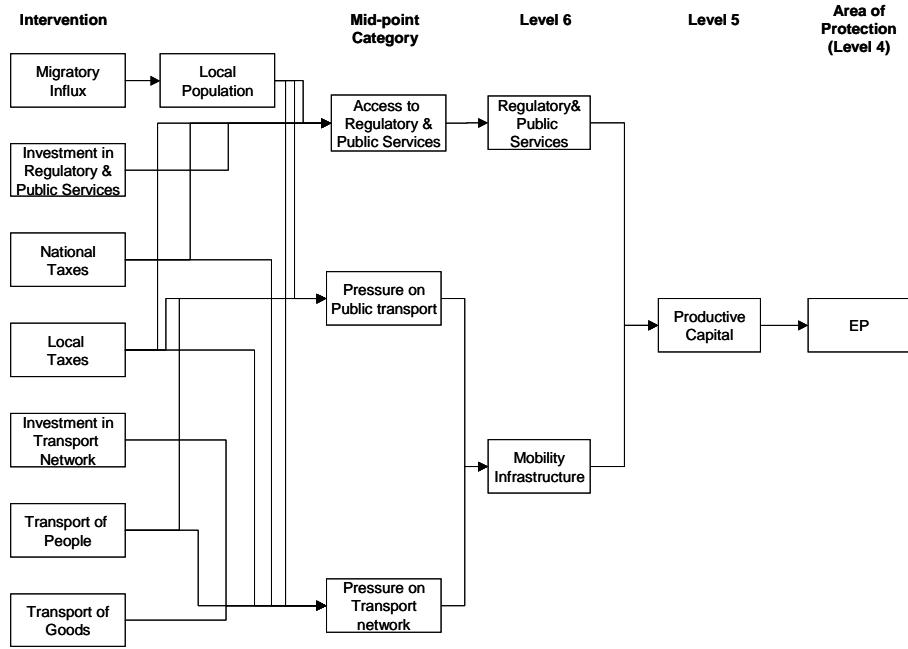
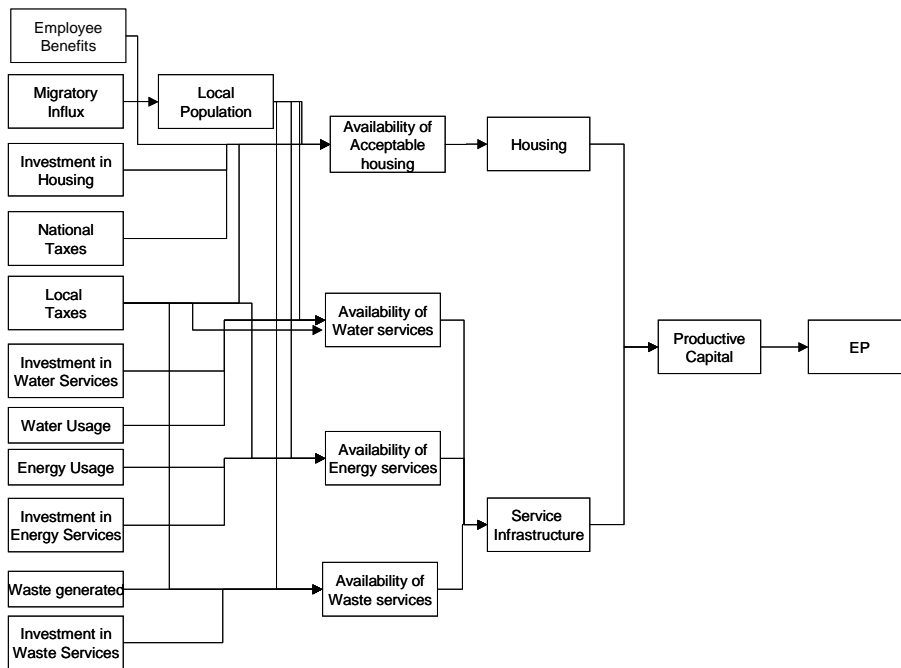


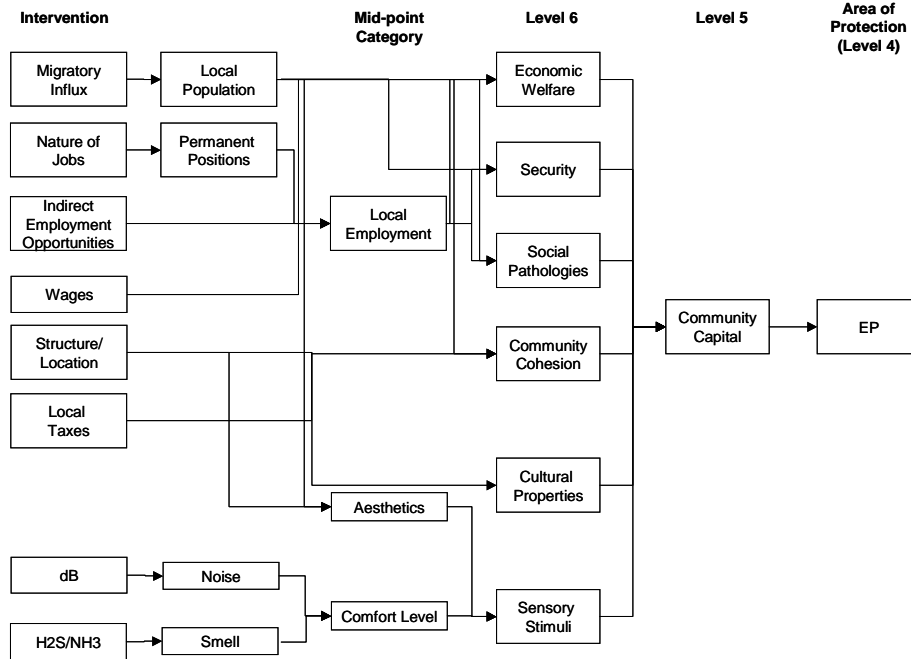
Fig 7. Causal Relationship Map for External Population: Human Capital



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

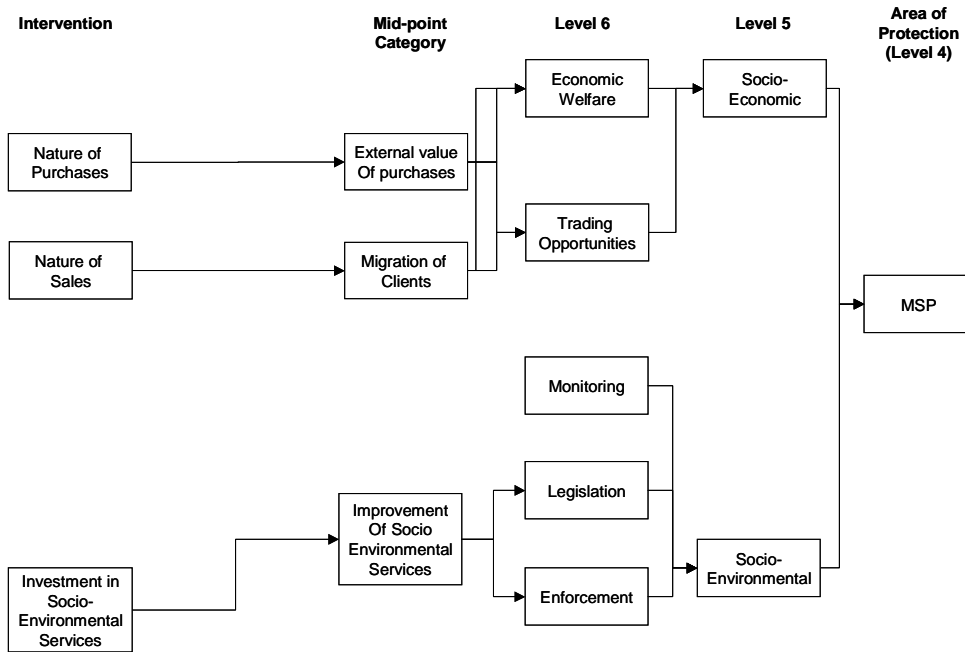


**Fig 9. Causal Relationship Map for External Population: Productive Capital (2)**



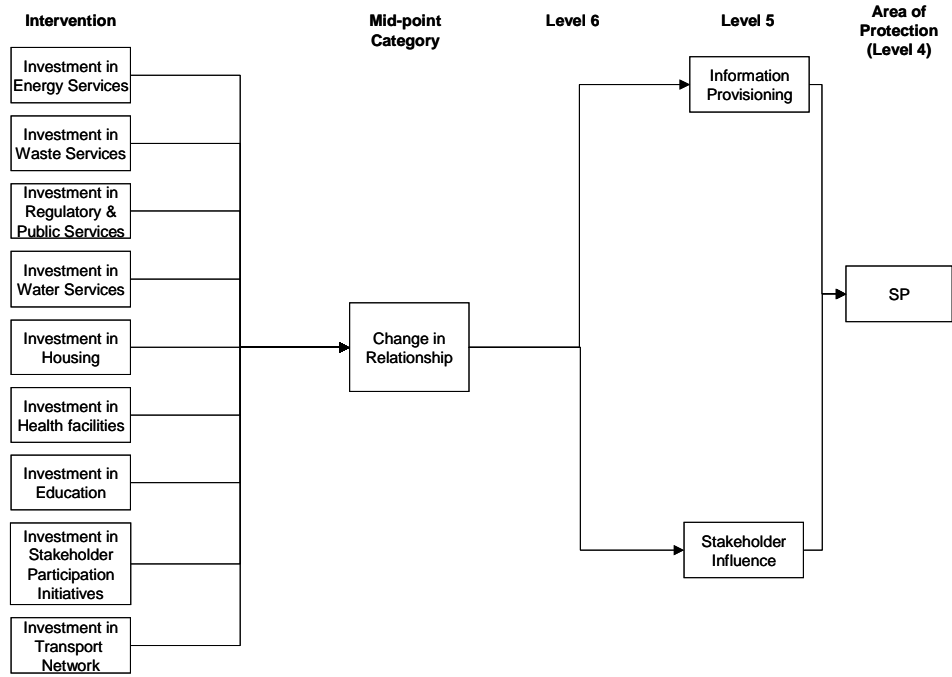
**Fig 10. Causal Relationship Map for External Population: Community Capital**

### 8.3 Macro Social Performance (MSP)



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

## 8.4 Stakeholder Participation (SP)



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