

17.1 What do we assess for a sustainable society from a manufacturing perspective?

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Abstract

Global recognition of sustainability appeared in the early 1970s as the rapid growth of the human population and the environmental degradation associated with increased consumption of resources raised concerns. Since 1987 a definition of sustainability is given by the Brundtland Commission. For a decade, sustainability has become a main challenge for manufacture because this could imply more competitiveness for manufacturer and because countries may use this issue as a trade barrier. While sustainability becomes an indispensable element, there are currently no scientifically convincing and widely accepted indicators for assessing sustainability. This paper presents the scope and boundaries of sustainability assessment and the aspects to be considered for selecting a proper set of indicators related to pressures, such as e.g. Methane emissions, and impacts, such as e.g. Climate change. Furthermore this paper also present a draft set of indicators within a novel approach for areas of protection.

Keywords:

Method, Evaluation, Indicator, Sustainability

1 INTRODUCTION

Global recognition of sustainability appeared in the early 1970s as the rapid growth of the human population and the environmental degradation associated with increased consumption of resources raised concerns. [1] The definition of sustainable development given by the Brundtland Commission, formally known as the World Commission on Environment and Development (WCED), is a development “that meets the needs of the present without compromising the ability of future generations to meet their own needs” [2]. Despite some proposed indicator sets for companies and countries [3, 4, 5], there are currently no scientifically convincing and widely accepted indicators for assessing sustainability [6, 7, 8] – especially for products and manufacturing processes. Several comparative evaluations of alternative indicators have been done over the past years. A range of very different evaluation approaches has been used for this purpose [9]. As the first step for scientific robustness of a sustainability assessment, this paper focuses on identifying suitable indicators, presenting a framework for this. The aspects or criteria for indicator evaluation are presented here as well as the interim results.

2 TOP DOWN AND BOTTOM UP APPROACH

Generally there are three approaches to develop indicators: top down, bottom up and combination of both. The top-down approach aims at a comprehensive consideration of all scientifically relevant aspects of sustainability. The bottom-up approach starts from the currently available data and tries to transform them into representative sustainability indicators. [10] A combined top-down and bottom-up approach is considered to develop a complete set of ecological, economic and social sustainability indicators (See Figure.1).

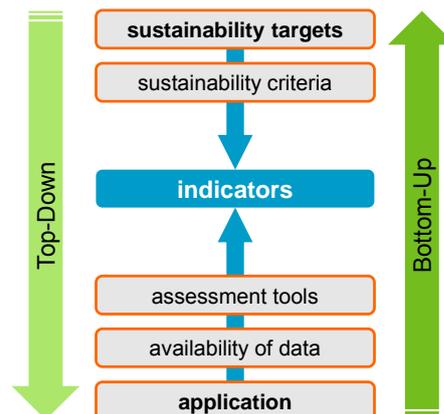


Figure 1: Sustainability indicators approach [11]

3 FRAMEWORK

3.1 Goal

First of all, it is an important step to identify what is the sustainability (goal of sustainability) before identifying proper set of indicators. There are many distinct approaches e.g. A = weak sustainability; B = weak sustainability operationalized; C = ecological economic strong sustainability; D = United Nations Environment Programme (UNEP) strong sustainability [12], (see Figure 2). For this research, the ultimate aim is taken in analogy from Meadows et al. 1972, which is “Materially sufficient, socially equitable, and ecologically sustainable” [1].

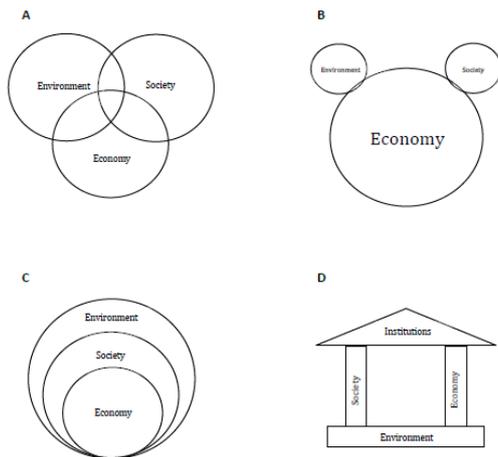


Figure 2: Sustainability approaches illustrated [12]

3.2 Scope - boundary and limitation

Next to identify the goal, next step is to define scope of the assessment, what is included and what not. The scope will help to judge also the relevance of the indicators. Here we refer to indicators is for manufacturing / production part of the society and related products. The focus is also the indicator that related to performance product, company or nation. Moreover to avoid subjective or individual preferable issues, the political, institutional and religion are not part of assessment.

3.3 Area of protection (AoP)

Instead of directly using the three pillars of sustainability Environment (Planet), Economy (Profit), and Society (People), this approach groups the sustainability aspects in form of three different areas of protection, Ecosystem, Humans, and Resources, which connect the three pillars. (See Figure 3). The main reason to propose this AoP is often economic aspect is related or has a connection to social and environment pillars.

The three areas of protections are:

- **Resources:** This area of protection covers the indicators related to planet and profit. Moreover it indirectly covers resource-aspects related to people e.g. via profit for people.
- **Humans:** This area of protection covers the indicators related to people and profit.
- **Ecosystem:** This area of protection covers the indicators related to people and planet.

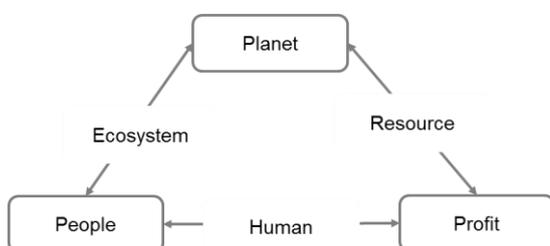


Figure 3: Illustration of relationship between the areas of protection and three pillars of sustainability assessment. (Own illustration)

4 INDICATOR EVALUATION

4.1 Methodology

For this paper only the top-down approach indicators are evaluated. The indicators are comprised from relevant initiatives, see 4.2. While these sets of indicators are applicable to all manufacturing, the level of relevance is different. For this evaluation, the experts have however to consider the global applicability, not in the specific one. In parallel, an

semi-quantitative evaluation scheme is established. All criteria are considered equally important for these indicators, i.e. with an equal weighting. The overview of the methodology present in figure 4.

At this stage, a limited number of experts have carried out the evaluation, mainly to test the approach, to ensure that the wider survey later this year will have a solid foundation. The experts, anonymous, have received three sets of information: indicators for resources (8 resource topics, 15 indicators), humans (6 humans-related topics, 8 indicators) and ecosystem (14 ecosystem topics, 25 indicators), separately. In addition to provide the evaluation results for the indicators, for each area of protection, the experts rank the topics in order of priority.

Three levels are used for this evaluation: fulfills, partly fulfills and does not fulfill. These levels are represented by characters A, B, or C. The aim is not to make an absolute evaluation but to sort the indicators and identify the most suitable one(s). For each evaluation criterion, the research team has used the “mode” of the results to select the representative evaluation result for each criterion; table 1 illustrates this step. Like the statistical mean and median, the mode is a way of expressing, in a single number, important information about a random variable or a population. As next step, the research team has compared these evaluation results across the indicators addressing the same topic. The mode, the element that occurs most often in the experts’ feedbacks of this sample is given in table 2.

For this preliminary result, the indicators have been evaluated by a small group of experts in the related areas i.e. Chemical Engineering, Environmental engineering, Industry ecology, Geoecology. This evaluation is based on expert judgment.

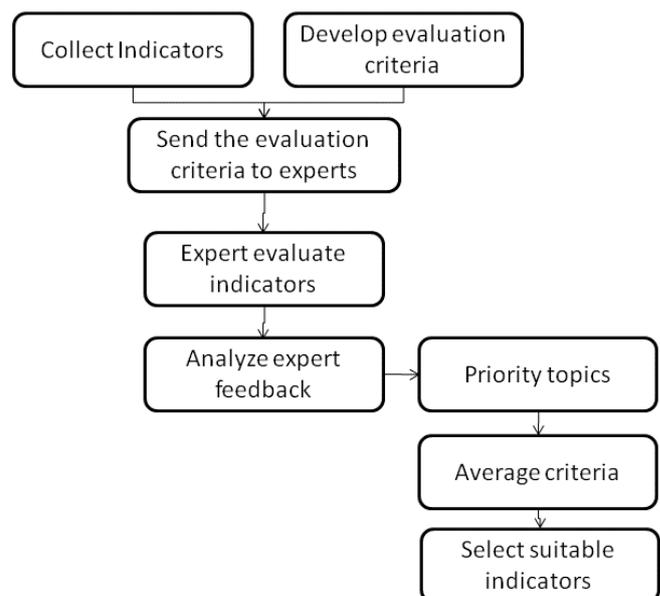


Figure 4: Overview of research steps

4.2 Source of indicators

The research team has compiled several indicators from well-known initiatives such as:

- European Commission Euro stat [13]
- EU Sustainable Development Strategy[14]
- Ecological Footprint network[15]
- Global Reporting initiative[16]
- European Commission Directorate General Environment[17]
- Circle of sustainability[18]
- Indira Gandhi Institute of Development Research[19]
- Ministry of Environment, Australia [20]
- Corporate sustainability management system [21]
- German National Sustainability Strategy[22]
- ...

4.3 Evaluation criteria and aspects for indicator selection

Taking into account the desired characteristics of the framework for SDIs from the OECD proposed by Hart, the criteria to evaluate sustainability community are [22]:

- **Relevant** – an indicator must fit the purpose you have it for – help measure progress toward a goal, raise awareness about a critical issue, or help local decision-making regarding natural resource use, etc.
- **Understandable** – an indicator must be simple and easy for everyone to understand.
- **Reliable** – people must trust the information that an indicator provides.
- **Provides timely information** – an indicator must give information while there is time to act or correct the problem.
- **Looks at the entire system** rather than at isolated part of it – indicator should try to highlight the links among ecological, economic and social aspects.
- **Clear and easy to measure** – having (standard) procedure to measure and with limited effort.

The above criteria do not consider some technical and scientific aspects, why three more criteria are added:

- **Effectiveness** - must be pointing to right direction and relate to the technical and function performance.
- **Robustness** - must be scientifically sound/defendable, its calculation involve no or acceptable/limited subjectivity (i.e. be reproducible) and limited/acceptable uncertainty (i.e. be sufficiently precise).
- **Practicality** - must be applicable with acceptable cost and duration/ time consumption and still meeting sufficiently well the methods potential: The following needs to be given: sufficient data availability (considering data quality, technological broadness and specificity, geographical coverage, age), limited complexity of implementation / needs for experts, sufficient availability of tool support, acceptable duration for development, and others.

Table 1: Illustration of individual criteria evaluate. Exp. = expert

Criteria	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Mode
Understandable (U)	U ₁	U ₂	U ₃	U ₄	U ₅	U _m
Relevant (R)	R ₁	R ₂	R ₃	R ₄	R ₅	R _m
Reliable (Re)	Re ₁	Re ₂	Re ₃	Re ₄	Re ₅	Re _m
Provides timely information (T)	T ₁	T ₂	T ₃	T ₄	T ₅	T _m
Entire system (E)	E ₁	E ₂	E ₃	E ₄	E ₅	E _m
Clear and easy to measure (C)	C ₁	C ₂	C ₃	C _m	C _m	C _m
Robustness (RO)	RO ₁	RO ₂	RO ₃	RO ₄	RO ₅	RO _m
Practicality (P)	P ₁	P ₂	P ₃	P ₄	P ₅	P _m

5 RESULTS AND DISCUSSION

5.1 1st top down indicator set

Based on the first evaluation, the top down indicators for the three areas of protection - as example for micro-level questions - are:

Ecosystem

- Climate change - Radiative forcing as global warming potential over 100 years (CO_{2eq})
- Land use - Soil Organic Matter

- EcoToxicity - Comparative Toxic Unit for ecosystems (CTUe)

...

Resources

- Land use - Soil Organic Matter
- Water use - Volume of water consumption (m3)

...

Humans

- Human Health - Disability Adjusted Life Years (DALY)
- Human - Quality of life (QoL)

...

5.2 Discussion

Currently many indicators especially from national level assessment e.g. European Union [13] focus more on the inventory level than on the entire system. However, this type of indicators has also many advantages e.g. understandable, clear and often easy to measure. In contrast with the comprehensive impact indicators, this needs scientific models, why it is often not easy to understand by some stakeholders.

Furthermore, many initiatives, e.g. UK [22] have a combination of inventory level indicators (e.g. CO₂ emission) and impact assessment level indicator (e.g. Global Warming Potential (GWP)). This may lead to confusion and also wrong interpretation because it looks at the different level of the problem or concerning issue.

The state of the art of indicators for the environmental pillar of sustainability is the most advanced one, compared with the other two pillars. For the area of protection "Humans", many indicators relate e.g. to living conditions, income, etc. but the impact of these two issues has not been derived (e.g. to express them as disability-adjusted life years (DALY), a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death).

The interim results presented in this paper are based on only a few experts and not all main indicators have been evaluated. Further work is needed. Finally, and based on the interim results, there is some overlapping in the selected indicators that needs to be solved.

6 ACKNOWLEDGMENTS

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Table 2: Example of evaluation scheme (extract from original list of ongoing work)

Topic	Indicator	Understandable	Relevant	Reliable	Provides timely information	Entire system	Clear and easy to measure	Robustness	Practicality
Ecosystem									
River water Quality	Chemical oxygen demand (COD)	A	A	A	A	C	A	A	A
	Biological oxygen demand (BOD)	A	B	A	A	C	A	A	B
Air pollution	kg emission	A	A	A	A	C	B	B	A
Waste	Volume of waste	A	A	A	A	C	A	B	B
Waste	Mass of waste (kg)	A	B	B	A	C	A	B	B
Eutrophication	Accumulated Exceedance (AE)	B	B	B	A	A	B	A	B
Acidification	Accumulated Exceedance (AE)	B	B	B	A	A	B	A	B
	Acidification Potential (kg NO ₂ eq)	A	B	A	A	A	B	B	A
Climate change	kg CO ₂	A	A	A	A	C	A	B	A
	Global warming potential-radiative forcing* (kg CO ₂ eq)	A	A	B	A	A	A	A	A
Ozone depletion	Ozone layer depletion (ODP)	B	A	A	A	A	A	A	A
...									
Resources									
Land use	Soil organic matter	A	A	A	A	A	A	A	A
	Area	A	A	A	A	B	A	A	A
Bird index	Number of bird index	C	B	B	A	C	A	A	A
Water use	Volume of water consumption	A	A	A	A	B	A	A	A
Resource depletion-mineral, fossil & renewable	Scarcity	A	A	B	A	A	B	B	B
...									
Humans									
Health and safety	DALY	B	A	A	A	A	B	A	A
	QALY	B	A	B	A	A	B	B	B
Wages and benefits	\$	A	A	A	A	C	A	A	A
...									

Note: A = Fulfills this criterion, B = partly fulfills the criterion, C = does not fulfill this criterion

*Global warming potential over 100 years

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