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# Sustainability criteria and sustainability compliance index for decision support in product development

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ABSTRACT

Sustainability criteria used for decision support in the product innovation process and aligned throughout the design process is one key element to efficiently introduce a sustainability perspective early in product development. The aim of this paper is to present an approach for identifying such sustainability criteria and to suggest a process for how these can be developed in any manufacturing company. The sustainability criteria are presented in a set of matrices, separating the criteria into product life-cycle phases and socio-ecological sustainability principles. In addition the paper presents a qualitative measurement scale for the criteria, called a sustainability compliance index that indicates to what degree a product or process concept performs in relation to a sustainable solution. The sustainability criteria were tested in different settings at a case company within the aerospace industry to give a first indication and evaluation of the ability to give guidance and support in bringing in a sustainability perspective when developing, evaluating and selecting different concepts in the early phases of product development.



## 1. Introduction

A product's socio-ecological impacts, positive and negative, throughout its life cycle are largely determined by decisions during early product development phases (McAloone and Tan, 2005). This is why it is important to efficiently introduce a socio-ecological sustainability perspective early in the product innovation processes (Bovea and Pérez-Belis, 2012; Inoue et al., 2012; Ramani et al., 2010). Hallstedt et al. (2013a) stated that if the identification of the sustainability aspects are included in the product requirement list, it would be easier to i) reduce the environmental impact and avoid costs, ii) plan for solutions as flexible platforms towards a sustainable solution, and iii) use sustainability as a driver for product-service system innovations. The importance of defining sustainability criteria and consider these on equal terms as traditional requirements, such as performance, cost and quality, from the very beginning of product development has also been emphasized by Waage (2007), Kaebernick et al. (2003), and Pujaria et al. (2004).

### 1.1. Sustainability criteria in product requirements

When sustainability-related criteria exist in product requirements today, they are often developed based on effects that are assumed to be desirable or not, along with being easy to assess. As an example, "minimization of energy" is often mentioned in regard to the sustainability of products, see e.g., Herva et al. (2011). To generally minimize the use of energy is good; however, there are forms of energy that can be utilized with no or very low sustainability-related impacts, like passive solar energy. This to say that it is not energy minimization per se that is the goal, but rather the minimization of certain types of energy that are associated with negative sustainability impacts.

*List of acronyms:* ACARE, Advisory Council for Aeronautics Research in Europe; DRM, Design Research Methodology; ECM, Electro-Chemical Milling; FSSD, Framework for Strategic Sustainable Development; LPT, Low Pressure Turbine; MM, Mechanical Milling; REACH, Registration, Evaluation, Authorisation and restriction of Chemicals; SBCE, Set-Based Concurrent Engineering; SCI, Sustainability Compliance Index; SLCA, Sustainability Life Cycle Assessment; SP, Sustainability Principle; TRL, Technology Readiness Level.

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This approach to sustainability and the ability to identify and represent an allowable sustainability compliant space for candidate designs is used in this paper. This also matches well with the first element (definition of feasible regions) of the first principle (mapping the design space) of Set-Based Concurrent Engineering set out by Sobek et al. (1999). Set-Based Concurrent Engineering (SBCE) is an approach to design products and services in which developers consider sets of ideas rather than single ideas. The first of the three principles of SBCE means in this work that identified sustainability criteria define a sustainability design space for the product life cycle. These criteria should be used to set targets, and guide the development of concepts and new innovations at the company. To use a similar approach as SBCE gives a better understanding to the engineers and product developers, as it is a familiar way of thinking in the engineering design community.

### 1.2. Sustainability indicators and readiness scales

Sustainability criteria can be developed to define the sustainability design space and thereby make more use of the detailed metrics such as indicators. In contrast to sustainability criteria, several sets of sustainability indicators or metrics have been explored during the latest years, e.g., Vogtländer et al. (2001), Feng et al. (2010), Lu et al. (2011), Inoue et al. (2012), and Joung et al. (2012). The difference between sustainability criteria and sustainability indicators has already been clarified by others, e.g., Renn et al. (2009), and Dreyer (2010). In line with their research, here a criterion is defined as a target of a prioritized aspect or the level of the aspect that we strive for (e.g., "no raw material used" and "no hazardous chemicals used"). An indicator is defined as a measurement or fact (qualitative or quantitative) that can indicate the state or level of the criterion (e.g., "material used in total and per unit of product" and "kilograms of persistent bio-accumulative and toxic chemicals used").

In the state of the art paper on industrial sustainability (focused on definitions, tools, and metrics) presented by Arena et al. (2009), the authors stated that in order to reach more sustainable solutions, the product development team must know what sustainability means, how sustainability can be achieved, and how sustainability can be measured. Criteria and indicators can be supportive in this. An indicator makes it also possible to compare and measure a relative difference between solutions. According to Stanners et al. (2007), there are several types of indicators. For example:

i) descriptive indicators, i.e., that present a state, pressure or impact;
ii) performance indicators, i.e., indicators that measure the distance between the current situation and the desired target value;
iii) efficiency indicators, i.e., that provide insight of efficiency through measuring input of resources per unit output.

An alternative approach to quantitative indicators is a scale of readiness or maturity levels with the purpose of providing a common understanding of the status and maturity level of a desired final stage. There are models with the purpose of describing the stages and communicate the level of sustainability integration in a company (Willard, 2005) and guide thinking and decision-making in relation to sustainability-oriented innovation (Network for Business Sustainability, 2012). Other approaches that target the managerial level in the company are the developed profiles and maturity levels for corporate sustainability strategies (Baumgartner and Ebner, 2010) and framework for different management levels with instruments to support sustainability activities (Baumgartner, 2014). More related to product development but still targeting the managerial level in the company is the EcoM2 model (Pigosso et al., 2013), which has the purpose of supporting managers on ecodesign implementation and management into manufacturing companies with focuses on process improvement. Comparable support for managers on a technology level has been used for several years within the aerospace industry by applying the Technology Readiness Level (TRL-scale) (Mankins, 1995). Hence, sustainability has mainly been discussed on an organisational level, and not directly to decision-making in design. There is a gap to bridge in including sustainability definitions into the decision-making process in engineering design.

### 1.3. Sustainability perspective in product development

If the decisions in product development influence the ability to reach more sustainable solutions, why is it still difficult to take those necessary decisions? The reasons may be several, yet two underlying problems are clear. Firstly, *the breadth and complexity of sustainability*, and, secondly *the time and data availability in the early design stages of the product innovation process.*

The first problem addressed is that sustainability criteria used today may be chosen because they are common or well-known, e.g., reduction of $CO_2$ emissions by x%. This is not enough to provide a complete picture of sustainability even if a set of common criteria would allow for a more complete picture than a single criterion alone.

The second problem addressed is that in industrial practice of conceptual product development there is neither time, nor data available to analyse sustainability in a rigorous manner. There is a need to derive pragmatic approaches that account for a full socio-ecological sustainability perspective also in these restrained circumstances, without compromising the completeness of sustainability.

In short, there is a need to efficiently introduce a sustainability perspective into the early stages of the product innovation process and support decision-making with tools that incorporate also a long-term and strategic perspective from a definition of success. The strategic importance is well recognized and in previous work the author and co-authors (Hallstedt and Thompson, 2011; and Hallstedt et al., 2013a) have identified and defined eight key elements for successfully implementing a strategic sustainability perspective:

1. ensure organizational support from senior management;
2. efficiently introduce a sustainability perspective early in the product innovation process;
3. utilize knowledge and experience of procurement staff in the earliest phases of the process;
4. include social aspects across the product life cycle and its value chain;
5. assign responsibility for sustainability implementation in the product innovation process;
6. have a systematic way for knowledge sharing and competence building in the sustainability field to inform decisions taken in future product development projects;
7. utilize tools for guiding decisions as a complement for assessment tools; and

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