# DECISION SUPPORT TOOLS FOR SUSTAINABILITY IN PRODUCT INNOVATION IN A FEW SWEDISH COMPANIES

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Companies are finding that customers increasingly demand "sustainable products" while also noticing economic benefits from eco-efficiency and other sustainability-related design approaches. Employees making product-related decisions need support tools to incorporate sustainability considerations — both at strategic (e.g. regarding product lines to develop) and operational levels (e.g. detailed design). This paper presents the results from a set of interviews that explored where and how sustainability considerations are taken into account in the product innovation processes of six Swedish companies. Results are presented as a map of the overall company operations in relation to a generic product innovation model, followed by a map of the places where sustainability considerations are made in that model. Some of the tools that are used to support those sustainability considerations are also briefly described. The conclusion is that there are some, but not sufficient, tools and methods to support inclusion of sustainability aspects in the product innovation processes of these companies.

*Keywords:* Sustainability, product development, innovation, tools.

## 1. INTRODUCTION

### 1.1. Sustainability Challenges and Product Innovation

The major global sustainability challenges now facing society, e.g., climate change, access to potable water, biodiversity loss, etc. provide cause for major concern with the long-term viability of human society [1]. Product innovation is a particularly critical intervention point for the transformation of society towards sustainability. Current socio-ecological impacts over product life-cycles are evidence that current practices are insufficient. Previous studies have focused on environmental aspects in product development (e.g. [2–7]), including case studies with companies in Sweden (e.g. [8, 9]). This study differs in two ways from these studies: first, by utilizing an alternative approach to sustainability considerations that extends beyond a focus on known environmental issues (presented in Section 1.2), and second, by using a general model of the product innovation process to identify where in the product innovation process sustainability aspects are considered (presented in Section 1.3).

### 1.2. A Framework for Strategic Sustainable Development

This study uses a framework for strategic sustainable development (FSSD) to provide an underlying framework to keep the ultimate goal of socio-ecological sustainability in focus. This FSSD emphasizes

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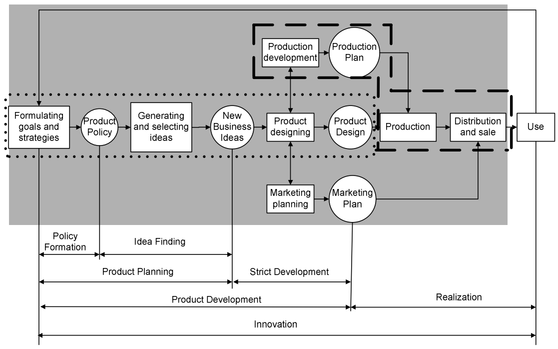


**Figure 1.** Operational activities at the participating companies mapped onto a generic product innovation diagram (adapted from Roozenburg and Eekels 1995). Four companies (A,B,C,F) work in the shaded areas, while one (E) focuses in the area of the dotted line and another (D) focuses in the area of the dashed line.

that for human society to be sustainable, it should stop systematic destruction of the ecological and social systems that it depends upon [10, 11]. This differs from some other working definitions of sustainability, which often suggest that "less bad is sustainable," e.g. products that use less energy or less water or emit less $CO_2$ are "sustainable products" [12]. This FSSD-based sustainability perspective has previously been integrated into product development procedures and processes [5, 13] and one study incorporates the FSSD's basic principles for socio-ecological sustainability into the main steps of life cycle assessment to then support product development [14].

### 1.3. A Product Innovation Model

This study uses a model of a generic product innovation process from Roozenburg and Eekels [15] (Figure 1) to guide the interviews. This model distinguishes between product development and innovation, such that product development is part of — but not the entire — innovation process. This model also distinguishes processes from the result of the processes. When exploring where tools are used, this model helped to differentiate between process-oriented tools (i.e. tools used during a process) and assessment or analysis tools (tools used to assess the outcome after a process has been completed).

### 1.4. Study Purpose

This study addressed the question: how and where is sustainability considered in the product innovation process at some different companies? Results from this study contribute to an initial descriptive phase of an ongoing project described in [16], and will be used to inform opportunities to better: (1) incorporate sustainability into the product innovation process, (2) connect strategic and operational levels in companies, and (3) develop specific methods and tools to support the previous two points. This study is guided by the extensive literature study by Baumann *et al.* [6], specifically with regard to how management, environmental, and product innovation issues are integrated, as well as where in the product innovation process various tools are used to consider both management and engineering perspectives.

## 2. RESEARCH APPROACH

### 2.1. The Companies

Six companies that were interviewed for this study:

(A) A producer of light tubes that last about four times longer than average tubes. The company has approximately 200 employees and an annual turnover of €40 M. One product engineer and the environment/quality manager were interviewed.

(B) A manufacturer of compaction machines with approximately 800 employees and an annual turnover of €230 M. The product development manager was interviewed.
(C) A company that develops, manufactures, and sells adaptable sealing solutions for sealing around cables or pipes that pass through walls. They have approximately 450 employees and an annual turnover of €95 M. The environmental manager and two product developers were interviewed at this company.
(D) A recycler of electronic materials with approximately 150 employees and an annual turnover of €22 M. The plant manager was interviewed.
(E) A product/technology development support company that has around 4000 employees. Four people were interviewed: Environmental Manager and Feature Specialist, Feature leader for the Environment and Fire Safety, Purchasing Director, Product Development Manager.
(F) A producer of jet engine components that has around 2300 employees and an annual turnover of around €465 M. One project manager, one product development engineer, and the environmental impact specialist were interviewed.

### 2.2. The Interviews

Between one and four people working with product innovation or environmental management systems were interviewed at each of the six companies during 2009. An interview guide with three sections was used to perform semi-structured interviews. The questions in that interview guide were sent to the interviewees two weeks prior to the interviews. Four researchers from BTH were involved in these interviews, with between one and three involved in each interview. The sections were as follows:

(i) Company Product Innovation Processes Compared to the Model: Using the Roozenburg and Eekels diagram of the product innovation process (shown in Figure 1), a comparison was made between where the company is working and where the company is including sustainability. First, it was determined where the company sees itself working within that diagram, e.g. is it mainly focused on product development (without production), is it mainly focused on production (without the development), or does it focus somewhere else? This is presented in Section 3.
(ii) Where Sustainability is Considered in the Company's Process: Where, with regard to the innovation model, are sustainability-related decisions taken? (presented in Section 4), and what sustainability-related tools are used, and where are they used? (presented in Section 5).
(iii) Sustainability-Related Opportunities: Where, with regard to the innovation model, do the interviewees feel that additional tools would be helpful, or where should additional decisions be taken with regards to sustainability considerations? (presented in Section 6).

## 3. COMPANY PRODUCT INNOVATION PROCESSES COMPARED TO THE MODEL

Primary activities in four of the companies (A,B,C,F) essentially covered the entire innovation diagram, i.e. each of these processes at the companies are addressed in the daily work. This is represented by the shaded area in Figure 1. The other two companies (D,E) had more targeted areas in daily operations. One is primarily a technology development company (E) and does not produce any physical products; this is indicated by the dotted line in Figure 1. Company (D) works with electronic waste, and as such is not involved in product innovation, though the company does have its own production plan regarding how to process the electronic waste.

Interviewees generally agreed that the Roozenburg and Eekels model was a good enough generic representation of their processes. One modification suggested by several of the companies was that "Product designing" and "Marketing planning" often have a significant influence on "Generating and selecting ideas", so there could be a link back to that box.

## 4. WHERE SUSTAINABILITY ASPECTS ARE CONSIDERED

All six companies have a sustainability aspect that plays a significant role in their product policy, as will be described in 4.1. However, none of these companies incorporated tools or decisions that suggested they include a strategic sustainability perspective in their complete process (i.e. a conscious step-by-step approach towards eliminating its contribution to global social and ecological un-sustainability while improving its competitiveness).

### 4.1. Policy Formation

All five of the companies that had daily activities in the policy formation area (A,B,C,E,F) had something in their product policy related to improving the sustainability performance of their products. For example, Company A's product inherently has an attribute that is generally considered positive from an environmental perspective: it is designed for long life times, so that fewer of the light tubes and thus the life cycle activities associated with production, transport, end-of-life, etc. are used. Company B has a strong focus on reducing energy use in their machines. Company C develops "sealing solutions" that are intended to improve safety and efficiency of the structures they are used in. Company E has 32 product features that must be addressed for the products they develop; five of these are specifically focused on sustainability-related issues. Company F has a strong emphasis on reducing component weight in recognition that the lighter their components are, the less fuel the airplanes will require.

In addition, two of the companies (E,F) have "environmental care" as one of their three core values. While it is not clear how this affects the product innovation process, these core values were repeated multiple times by interviewees when they were asked about sustainability. They also stated that they have environmental issues in their minds during their daily work, and suggested that is largely influenced by these core values.

### 4.2. Idea Finding

Companies used the sustainability aspects from their product policies as inspiration for idea finding. For example, long-life, light-weight, or low energy use over the life cycle were motivating factors in the generation/selection of ideas, and in the assessment of new business ideas. It was not clear, however, if or how a more comprehensive or strategic sustainability perspective was explicitly included in any of the companies during idea finding, either for the generation of new ideas or for the evaluation of ideas.

### 4.3. Strict Development

There was consistently good alignment between product policy and the strict development phase for those sustainability considerations that were included in the policy formation phase, i.e. if something was stated in the product policy, it was taken into account in some way during the development phase. Similarly, if something was lacking in the product policy, it was not likely to be considered in the development process. In short, sustainability aspects were not added for the first time in the development phase.

### 4.4. Realization (Production, Distribution, and Sale)

All companies have an environmental management system (EMS), which is typically focused on facilities and operations management during production. Several companies also stated that they considered impacts outside of their own facilities, such as the distance between suppliers and their own facilities when choosing suppliers in an effort to reduce transports for both economic and environmental reasons.

Social aspects of sustainability were often mentioned here, also, with regard to the company's own production facilities, e.g. worker exposure to hazardous emissions, high noise levels, or ergonomically unfriendly conditions. With the two larger companies (E, F), there was explicit reference to also considering working conditions at their suppliers.

### 4.5. Realization (Use)

All of the companies in this study had a life cycle perspective of their product that included the use phase, thus they saw value in improving the sustainability performance of their product during its use phase even though the product would no longer be in the company's possession. At the same time, the sustainability aspects that companies considered were usually partially aligned with other considerations in the process, primarily legislation and cost. For example, fuel efficiency is a significant consideration when developing products at several companies both to comply with legislation and to lower operating costs for their customers. Of course, fuel efficiency is also commonly considered a sustainability aspect.

One of the companies (E) had done a significant amount of work to determine the life cycle environmental impacts of their product, and had taken steps to develop key indicators to address the major environmental impacts. This resulted in five features that were included in the overall 32 product features that were set for each development project. The other companies had made educated estimations of sustainability impacts across their products' life cycles, though they seemed less thorough in their identification of the key sustainability impacts.

## 5. TOOLS TO SUPPORT SUSTAINABILITY CONSIDERATIONS

Here tools are listed that were identified during this study, along with a brief description of how they were being used. During these interviews, the interviewees showed relatively limited tools or decision support in the area of social sustainability. Additional tools are used for other, though sometimes related, purposes; e.g. prioritization matrices, computer-aided design (CAD) and other simulation tools, etc. Focus here is on those tools that are more directly and distinctly connected to sustainability.

### 5.1. Material Lists

All of the companies had some type of guidance for material choices in the form of a list. These lists were typically based on substance lists directly from legislation such as Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and customized specifically for the company. They often took the form of lists of "banned substances" that should not be used at all and a list of "substances to avoid" that should only be used in special circumstances or with the intent of phasing the substance out. Sometimes these lists applied only to substances that would be used in products, and other times these lists applied also to substances that might be used in the production process. Other material lists include PRIO — a web-based tool developed and maintained by the Swedish Chemicals Agency — to work toward reducing risks to human health and the environment. Companies also stated that they often must comply with requests from customers to not use particular substances. Nearly always, these material lists were used in product designing and often also for verification after the product design was finalized.

### 5.2. Environmental Management System (EMS)

All of the interviewed companies had an Environmental Management System (EMS) following ISO 14001. The EMSs were mainly used in connection with production to structure and organize the companies' work regarding known environmental impacts like reduction of emissions, substitution of chemical, and reduction of transport.

### 5.3. (Product-based) Environmental Impact Assessment (EIA)

Three of the six companies (C,E,F) used Environmental Impact Assessments (EIA) to assess their products' environmental impacts. These EIA tools were company specific, and vary somewhat in complexity and completeness with regard to both environmental impacts that were considered, and to the extent that the product's life cycle activities were addressed. Common among the companies is that the EIA was mainly used late in the product development process to assess already developed concepts or products where many design decisions had already been taken. Thus, the tool was in the "product design" circle of the product innovation model (and not the "product designing" box), and had relatively little impact on the development of the current product. Learning from the EIA, however, was sometimes utilized in significant ways to innovate in future development projects.

### 5.4. Life Cycle Assessment (LCA)

Two companies (E, F) have in their product development process the option to conduct an LCA on their products after they are designed in order to verify environmental performance. Two other companies (A,B) do not currently use LCA, but would like to explore its use for comparing new products with existing or older products to ensure that newer products do have an improved environmental performance or in order to have a better understanding of the relative environmental impacts of various aspects of their product. Company (C) expressed interest in LCA-like approaches to better understanding the environmental consequences of their product, but were mostly interested in the life cycle approach, not LCA specifically.

## 6. SUSTAINABILITY-RELATED OPPORTUNITIES

Interviewees were asked about the sustainability-related gaps that they saw in their companies; this section presents a summary of their responses.

- Use of an LCA-based Tool:
  Three companies (A,B,C) expressed an interest in having an LCA-based tool that would enable them to quantitatively compare product concepts, as well as to compare existing products with new products to see if they have improved sustainability performance. As noted above, two of the companies were already using LCA tools.
- More Information about Early Life Cycle Stages of Materials:
  There is a need for more data regarding the sustainability impacts from early life cycle stages of materials. A distinction can be made between general data regarding sustainability impacts for a type of material (e.g. aluminum requires X% more energy than steel to produce) and specific data from a company's own supply chain. While access to and use of this information varied greatly among these six companies, all were interested in having more data.
- Clearer Guidance During Idea Generation:
  Understanding that the only concepts that can be developed are those that are thought of during idea generation, one interviewee suggested that it would be helpful to have more sustainability-focused thinking during the idea generation. Interviewees at other companies echoed this to greater or lesser extents.
- Support in Connecting Sustainability Aspects to "The Bottom Line":
  Though suggested in different ways by different companies, there is clearly a need for evaluating how the consideration of sustainability aspects during product innovation can influence the economic success of the company. To one company (C) this meant showing how a focus on sustainability issues could directly reduce costs or lead to improved efficiency and production. Another company (B) talked about this with regard to the cost of operating their product, with the explicit assumption that if they could show reduced life cycle costs, this would lead to more success for the company.
- Life Cycle Consideration of Other Impacts of Substances:
  The electronics recycling company (D) pointed out that many companies have lists that guide substance selection, and that often those lists are directly or indirectly based largely upon known environmental impacts. The interviewee said that there are other substances that might not be toxic, but that they can cause other "problems" in the material life cycles, e.g. with regard to the recyclability of other materials. He suggested that material guidance lists could be adapted so that they guide toward the use of materials that have more favorable life cycle attributes, e.g. are more easily recycled.

## 7. DISCUSSION

Most of the decision processes and tools described by the companies were based upon known environmental impacts. In some ways this is considered to be the most practical, i.e. why worry about something if it is not known to be a problem? On the other hand, increasing dependency on technologies that are not known to be 'safe' can lead to future problems [17]. For example, the material lists used by the companies in this study are mainly intended to avoid using materials that have known environmental impacts and materials that are prohibited by legislation. Material lists that can be used for sustainability considerations also could consider other socio-ecological aspects, e.g. material scarcity, working conditions for people involved in the material's life cycle, and more directly: materials that are not currently known to cause problems, but are also not known to be 'safe'. In line with the above-mentioned FSSD, a precautionary approach is more strategic, especially given the rapid development and increasing pace at which new technologies are implemented and this necessitates ensuring that today's solutions do not lead to future problems.

Identification of key sustainability features in product requirements is an example of how to insert the sustainability aspects in an operational way. One of the six companies (E) has undergone a rigorous process to identify key sustainability features that it can then include at the requirements level. This process was specifically focused on identifying sustainability features, and resulted in five features that insert the sustainability aspects in an operational way into the workspace of the designers and engineers. These requirements must be set and met during product development. Several of the other companies have included sustainability-related aspects at the product policy level. This often translates into one (possibly more) specific requirements that also come into the workspace of the designers and engineers. With these other companies, the selection of these key aspects at the product policy level appears to be less rigorous from only a sustainability perspective, and instead more of a combination of what is perceived to be good for both socio-ecological sustainability and economically for the company and its customers. This is not to say that one approach is better, but only to acknowledge a different approach and raise the question for possible further exploration.

There are opportunities for knowledge and experience from working with a company's environmental management system (EMS) to support product innovation, e.g. to inform material and process selection during product development. EMSs are often in place in order to ensure compliance with legislation regarding substance use and handling, and these systems are reviewed periodically in order to ensure that the company keeps the certificate.

All of the companies, to a greater or lesser extent, use a forecasting mindset that suggests that the main negative environmental impacts should be identified and reduced. This is a good approach when there are significant opportunities with "low-hanging fruit" — opportunities for major environmental improvement in the short term. However, a different approach is needed when these "low-hanging fruit" have been "harvested" and it is desirable to continue to advance the way in which sustainability is used to drive innovation. In order to continue to find significant sustainability improvements, it is possible to use the FSSD approach to look to different system levels and explore opportunities for optimization and innovation. These opportunities bring new challenges with regard to how companies collaborate across value chains.

Using a general model of the product innovation process to map where various tools or methods are actually used to consider sustainability aspects in company processes is expected to aid in the continuation of this research project with its aims as described in Section 1.4.

## 8. CONCLUSIONS

This study maps sustainability considerations of six companies on a general model of the product innovation process, and shows how all six companies have taken steps to consider sustainability aspects through the tools used and decisions taken during their product innovation processes. However, there is significant opportunity to better incorporate tools and decisions that demonstrate a strategic sustainability perspective throughout the process that will allow for an intentional step-by-step approach towards eliminating its contribution to global social and ecological un-sustainability while improving the company's competitiveness.

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