2 STRATEGIC DECISIONS GUIDED BY TOOLS AND METHODS BASED ON SUSTAINABILITY QUESTIONS

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Product development 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. Several research projects have been carried out to explore, develop and improve methods and tools for Sustainable Product Development.

A general conclusion from this research is that the support needed for making sustainability-related decisions are not systematically integrated in companies today. However, this research also indicates that it is possible to create generic methods and tools that aid the integration of sustainability aspects in companies strategic decision-making and product development. These methods and tools can be used to guide the prioritization of investments and technical optimization on the increasingly sustainability-driven market, thus providing a foundation for competitive sustainable product development.

Keywords: Sustainable Product Development, Strategic Sustainable Development, Backcasting.

1. INTRODUCTION

1.1. Product Contribution to the Sustainability Problem

Product development is a particularly critical intervention point for the transformation of society towards sustainability. Socio-ecological impacts of resource extraction, production, distribution, use and disposal of products are evidence that current practices are insufficient. A product's impacts — positive and negative throughout its life-cycle — are largely determined by decisions during product development.[1–3] Thus, it is imperative to integrate a sustainability perspective in methods and tools for product development. Businesses taking a leading role in this development are likely to become increasingly more competitive. They will more clearly see the business case in systematically diminishing their contribution to society's un-sustainability.[4] This includes improved brand value, improved control of costs, increased efficiency and loyalty of staff, and better anticipation of new market opportunities.[5]

1.2. Measures for a Change

There are many early signs of ecological sustainability considerations becoming part of strategic decision making in business. Many companies have implemented Environmental Management Systems (EMS), performed Life-Cycle Assessments (LCAs), launched cleaner production and ecodesign initiatives[6–10], started to use ecological indicators like eco-efficiency and begun to eco-label products. The recent emergence of concepts such as 'Corporate Social Responsibility' (CSR) and 'Triple Bottom Line' indicates that companies now also have started to take the social sustainability dimension into more professional consideration.

1.3. Sustainable Product Development

In spite of all these promising market interventions, society in general still remains on an un-sustainablecourse. Without integrating a framework for strategic decision making in relation to societal development towards the full scope of socio-ecological sustainability in the future, it is supposedly difficult to consider the most relevant aspects of sustainability, to identify the interlinked strategic business opportunities and to inform appropriate methods and tools. In this research, the focus is on product development with a full systems perspective on socio-ecological sustainability, a process which will be referred to as "sustainable product development" (SPD).

2. A FRAMEWORK FOR STRATEGIC SUSTAINABLE DEVELOPMENT

The tools and methods for Sustainable Product Innovation, described in later sections, are based on a Framework for Strategic Sustainable Development (FSSD) that aims at clarifying how our future society must be constituted on the most basic level to be sustainable. This framework also suggests how organizations can plan and act to support society's transformation towards such a society while avoiding financial risks associated with unsustainable practices and foreseeing new business opportunities. This planning challenge is dealt with at five different interacting levels:[9,11]

Level 1.
The system (in this case, the organization within society within the biosphere).
Level 2.
Success in the system (in this case, products supporting society's compliance with principles for sustainability).
Level 3.
Strategic guidelines to arrive at success in the system (in this case mainly "Flexible", "Direction" and "Pay-back" as described below).
Level 4.
Actions aligned with the strategic guidelines to arrive at success in the system (in this case, mainly product life-cycle improvements).
Level 5.
Methods, tools and indicators designed to help prioritize and monitor actions that are strategic to arrive at success in the system.

This framework has been developed in a scientific consensus process into a concrete planning method called backcasting from sustainability principles (BSP).[9,11–18]. The current wording of the sustainability principles (SPs) (level 2) is:
In the sustainable society, nature is not subject to systematically increasing.

I. concentrations of substances extracted from the Earth's crust,
II.concentrations of substances produced by society,
III. degradation by physical means, and, in that society,
IV. people are not subject to conditions that systematically undermine their capacity to meet their needs.

Backcasting from sustainability principles is in practice often run by an external facilitator that takes an inter-disciplinary group of company representatives through the following ABCD working procedure:

A. Discuss the framework as such, to reach acceptance for it as a shared mental model for the work to come.
B. Start an iterative process of brainstorming, describing current practices in relation to the SPs.
C. Identify alternative future solutions or visions that are likely to comply with these principles.
D. Evaluate and prioritize between early strategic actions (investments) to close the gap between B and C. The main three strategic guidelines for this prioritization are:

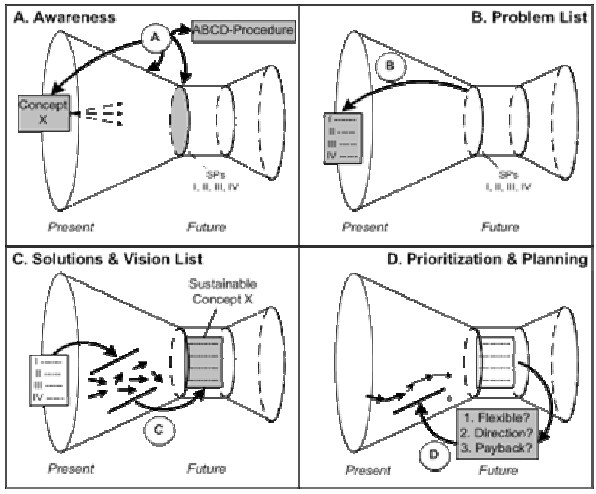

Figure 1. The A-B-C-D procedure (Reproduced from .[18] Step A: Start by agreeing on a mental model of the concept of study (Concept X), the sustainability challenge, the Sustainability Principles (SPs) (I–IV) and the ABCD procedure as such. Step B: Then identify present practices that are problematic with respect to the SPs and assets for solving the problems. Step C: Continue with brainstorming to list potential solutions to the problems and envision new sustainable concepts. Step D: Based on the B- and C-list and strategic guidelines, prioritize actions into a strategic plan.

1. choose "flexible platforms" or investments that are likely possible to develop further towards success as defined by the SPs and other goals set up by the organisation (this guideline is called "Flexible" in step D of Figure 1),
2. seek to reduce the contribution to society's violation of the SPs ("Direction" in Figure 1),
3. strive for sufficient return on investment soon enough to continuously reinforce the process ("Pay-back" in Figure 1).

In the decision regarding an individual investment, though, the three guidelines need to be assessed in a dynamic interplay between each other (Figure 1). Previous studies have repeatedly shown how this framework can assist businesses and municipalities in grappling with the complexity of the sustainability challenge and turning what is often perceived as a cost into an opportunity for innovation and cost savings.[16,19,20]

3. SUSTAINABLE PRODUCT INNOVATION RESEARCH

Several research projects have been carried out at BTH to explore, develop and improve methods and tools for Sustainable Product Development (SPD). In this paper, three SPD tools are presented and a brief overview of the research methods, the main results as well as the main contributions to form a methodological foundation for sustainable product development is described. Data have been collected through several surveys, including interviews, questionnaires and observations.

The main basic approach is to combine the above described framework for strategic sustainable development (FSSD) built on backcasting[a] from basic socio-ecological sustainability principles with a standard concurrent engineering development model. The new methodology is supposed to promote identification of sustainability problems and stimulate and guide generation of possible solutions. The wider purpose of all of this is to support pro-activity and transformation of society at large towards sustainability.

[a] Backcasting means, in short, "looking back from an imagined point in the future in order to explore strategies to get there."

4. METHOD FOR SUSTAINABLE PRODUCT DEVELOPMENT (MSPD)

4.1. Development of MSPD

An initial survey registered product development procedures and the environmental work in ten Small- and Medium Sized Enterprises (SMEs) as well as their need for, and desired characteristics of, a new method for integrating sustainability aspects into the product development process .[21] The survey was performed parallel to, and gave an additional basis for, the development of the first structure of a Method for Sustainable Product Development (MSPD).

A restructured and enhanced Method for Sustainable Product Development, including a modular system of guiding questions, was developed and tested during a one-year period in two different types of companies in Sweden .[22] This second survey was followed up with a questionnaire and an in-depth interview with specific questions for design for answering following research questions:

- *Can potential sustainability problems of current products be identified and does the new suggested MSPD provide guidance in finding alternative solutions to the present or planned products?*
- *How user-friendly and flexible is the new suggested MSPD, and what are the needs for further research and development?*

4.2. Results from the MSPD-Case

The first survey showed that for the SMEs in this investigation the question is not whether environmental aspects need to be considered, but rather what should be considered and how. There was a wish for a computer-based method/tool that, during the ordinary product development process, assists them in identifying potential risks for environmental problems related to their products. The initial survey also registered the company's product development procedures and environmental work. From this survey, together with a literature study, a generic model of a product development process was identified and then used as one part of the MSPD.

The second survey tested a computerised version of the MSPD. The MSPD consisted by an introduction manual, a modular system of guiding questions to stimulate brainstorming, and a prioritization matrix to aid decisions about which solutions to carry forward to the next stage. The MSPD was design to be flexible in that perspective that it could be used together with different types of existing methods in companies. The test of the MSPD showed that parallel use of existing methods was free from problems.

The guiding questions are derived by considering basic sustainability principles and a full life-cycle perspective, and thus function as creative constraints and facilitate multi-disciplinary problem solving and decision-making (See Table 1).

4.3. Main Contributions from the MSPD-Case

Asking guiding questions derived by considering basic sustainability principles and a full life-cycle perspective is a main result from this research and is also a key feature in the foundation for sustainable product development presented in Ref. 23.

The second study also confirmed a desire from product developers for some kind of sustainability-expert support for getting a quick overview of the main sustainability aspects of a given product category before continuing with the MSPD work on their own. This is part of the background for the "templates" approach described in the next section.

5. TEMPLATE FOR SUSTAINABLE PRODUCT DEVELOPMENT (TSPD)

5.1. Development of TSPD

Templates for Sustainable Product Development (TSPD), was developed based on the result from the research about MSPD and consist of some generic key questions. An idea of "templates" for sustainable product development (TSPDs) was to increase the ability of company in-house product developers to see and apply the overall long-term sustainability picture as an aid for identifying a

suitable mix of dematerialization and substitution investments. The idea was also to give them a means for communication to top management in order to receive support for actions.

Whether the TSPD approach has the desired qualities was investigated in an evaluation case study at the Matsushita Electric Group.[24] The effect of the template approach was evaluated in three steps.

a. What was the sustainability performance of the Matsushita TVs before the approach was introduced?
b. Was the template approach applied as intended?
c. What indications of resulting product-related sustainability improvements could be found?

5.2. Results from the TSPD-Case

This study indicates that the TSPD approach captures overall sustainability aspects of the life-cycle of product categories. The TSPD approach has in the Matsushita case demonstrated to be a functional basis for dialogue about sustainability-related issues within the company and thereby facilitating sustainability-related decision making later on.

Furthermore the TSPD approach.[24]

– has the ability to shift the focus of the client organization towards its sustainability gap. The mechanisms for this were the introductory training and the oral and written dialogues facilitated by the templates.
– has the ability to facilitate a common understanding among different organizational levels of major sustainability challenges and potential solutions.
– has the ability to facilitate a continued dialogue with external sustainability experts, identifying improvements that are relevant for strategic sustainable development. In this case study, Matsushita gradually deepened their dialogue with external experts and showed progress in relation to the sustainability requirements identified in the initial sustainability assessments.

Table 1. Examples of questions for some of the SPA modules. *The questions are marked with B or C and principles for sustainability (PS) 1-4, which represent the B-step and the C-step in the ABCD-analysis and the basic principles for sustainability 1, 2, 3 or 4 on which the questions are based.*

SPA module	B-or C-step and principles for sustainability (PS: 1–4)	Example of questions
Product function	B/PS: 1, 2, 3, 4	Is there a dissipative use of the product and does the product consist of; metals; chemicals; resources from ecosystems; resources put in global human need perspective?
	C/PS: 1, 2, 3, 4	Are there any product types with no dissipative use of the materials, that can be incorporated into societal cycling of materials (low material losses) or even into tight technical loops with no or very small losses to the environment and that fulfil the customer needs?
Product design	B/PS: 1	Are fossil fuels currently needed for the usage of the product?
	C/PS: 1	How can the product be designed to use renewable energy sources (directly or via electricity) during the usage phase?
Material type	B/PS: 1, 2	What materials are used that cannot be incorporated into the ecosphere, e.g. scarce metals or chemicals non-degradable and bio-accumulating?
	C/PS: 1, 2	What alternative materials can be used that can be more easily incorporated into the ecosphere, e.g. relatively abundant metals, chemicals that are relatively easily degradable and renewable materials?

5.3. Main Contributions from the TSPD-Case

The TSPD approach, an offspring of the MSPD, was developed for a fast and effective overview assessment of the sustainability gap for specific product categories. TSPD was also used successfully in an overview assessment and as part of a procedure for a sustainability-driven design optimization.[25]

6. TEMPLATE FOR ASSESSING DECISION SYSTEMS (TADS)

6.1. Development of TADS

The purpose for developing the TADS approach was to answer the research questions:

- By what approach can sustainability integration in a company's strategic decision system be assessed?
- At what organizational level should what type of support be used to facilitate decisions that effectively take the company towards sustainability?
- What would be some generic guidelines for improving a company's strategic decision system?

A two-stage assessment approach based on guiding questions was developed and tested in two small and medium-sized companies and two large companies.[26] The strategic capabilities of their decision systems were studied – both in general and in relation to sustainability. The results were validated against the experiences made by two management consultancies with a large number of clients.

The two assessment stages were:

a. Inventory of current general and sustainability-oriented strategic decisions systems.
b. Strategic Capability Assessment of these decision systems – both in general and in relation to sustainability.

6.2. Result from the TADS-case

The result of this study presents a new assessment approach with the ability to identify a list of key improvements for how a company could integrate sustainability in its strategic decision system. These recommendations are[26]:

– creating an overarching supporting organizational context, including senior management awareness and commitment to a widely adopted definition of sustainability, sustainability integration in business goals and policies, and, to that end, adequate resource allocation,
– institutionalizing internal company capacity building and communication on sustainability,
– introducing integrated methods, tools and indicators for both senior management and product development teams that focus on how to close the gap between the present situation and long-term socio-ecological sustainability.

The study indicates that the assessment approach could be used as a generic template to assess the current state of sustainability integration in company decision systems.

6.3. Main Contributions from the TADS-Case

In earlier projects the focus has been on support methods and tools for integration of sustainability aspects in product development. This study widens the perspective to include processes and methods and tools for communication and cooperation across organizational levels. It shows that SPD methods and tools are important but not enough for implementing sustainability in companies. It provides guidance for how to systematically integrate sustainability in companies' strategic decision systems to support the development of more sustainable products.

7. DISCUSSION/CONCLUSION

A general conclusion from this research is that the support needed for making sustainability-related decisions is not systematically integrated in companies today. However, this research also indicates

that it is possible to create generic methods and tools that aid the integration of sustainability aspects in companies strategic decision-making and product development.

A unique contribution to a foundation for a sustainable product development is the combination of a framework for strategic sustainable development (FSSD), based on backcasting from basic sustainability principles, with a concurrent engineering product development model. The resulting method for sustainable product development (MSPD) has as a key feature a modular system of guiding questions, derived by considering the sustainability principles of the FSSD and the product life-cycle.

The main idea of using guiding questions is to avoid detailed rules and prescriptive guidelines. The purpose is instead to raise the awareness and knowledge about product-related sustainability problems and opportunities among business leaders and product developers and to open up for a creative dialogue and innovation within basic sustainability constraints. The SPD-methods and tools stimulate knew ideas and at the same time have an educated effect when the users are finding the answers to the questions. When using the SPD-tools and methods in practise, there is an advantage if the users also get an introductory education in the FSSD. However, this is not a requirement in order to use the tools. One of the main strengths with MSPD and TSPD is also that they facilitate an implementation of a strategic sustainability perspective in company processes and routines instead of rely on the competence level of the company employees in strategic sustainable development.

The research surveys indicated that there is sometimes a desire for a quick overview of the sustainability performance of a specific product category, to guide early strategic decisions before the more comprehensive and detailed work with the general MSPD is undertaken, or, alternatively, when an overview is sufficient to make decisions. This is the objective of the templates for sustainable product development (TSPD) approach presented in the paper. It is also shown that TSPDs facilitate communication between top management and product developers and thus positively influence the company's capacity to find product improvements that are relevant for strategic sustainable development in the longer term.

An important conclusion from this work is that to reach maximum efficiency in finding viable pathways towards sustainability, it is necessary to coordinate different methods and tools that are useful for sustainable product development and integrate them into the overall decision-making processes at different levels in companies. In order for these methods and tools to be used properly, a commitment from senior management is needed. This should include integration of sustainability aspects in business goals and appropriate resource allocation. A new strategic capability assessment approach has therefore also developed in this research, as well as guidance for how to systematically integrate sustainability in companies' strategic decision systems.

In summary, the contributions of this research constitute support for prioritization of investments and technical optimization on the increasingly sustainability-driven market, thus providing a unique foundation for competitive sustainable product development. The wider contribution of all of this is to support societal transformation towards sustainability.

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