Modernising Ecodesign

Ecodesign for innovative solutions

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Modernising Ecodesign – Ecodesign for Innovative Solutions
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Doctoral thesis

Academic thesis, which with the approval of Kungliga Tekniska Högskolan, will be presented for public review in fulfilment of the requirements for a Doctorate of Engineering in Machine Design. The public review is held at Kungliga Tekniska Högskolan, on Lindstedtsväg 26, F3, at 10.00 on Mars 24, 2006.
Abstract

The focus of environmental work in manufacturing companies has increasingly shifted from end-of-pipe solutions to the environmental performance of products and services. The product development process is central to creating value for customers. This thesis argues that companies can simultaneously create value for consumers and be profitable while taking environmental considerations into account.

Modernising ecodesign means taking advantage of environmental benefits and the innovation potential when developing solutions rather than using ecodesign simply to ensure that legal requirements or customer demands are met. Ecodesign is a strategic issue and should be included in early product development activities, such as for project selection and when setting product targets. There is also need to perform ecodesign according to the characteristics of specific development processes as for radical product development or when developing integrated solutions, using a combination of services and products.

This thesis reports on the findings from five different research studies, all of which adopted a qualitative approach in which the emphasis falls on exploring and creating understanding and meaning. The studies focused on three areas of ecodesign: A) rethinking approaches for manufacturing companies, B) setting environmental project targets and project selection and C) redesign of products.

Recommendations on how to modernise ecodesign have been developed and can be summarised in six points:

- Perform ecodesign both vertically and horizontally in a company.
- Increase interaction between organisational units.
- Take advantage of innovation potential in products, services, user behaviour and the delivery and take-back systems.
- Take environmental considerations into account in the project selection process.
- Set environmental targets for ensuring that environmental considerations are taken when developing innovative solutions.
- Develop ecodesign procedures that fit the characteristics of the development process.
Acknowledgements

Since the acknowledgements are the one part of a thesis that most people actually read, I have taken the opportunity to include a ‘thesis light’. Here is what I recommend:

Perform ecodesign both vertically and horizontally in a company, increase interaction, take advantage of innovation potential, take environmental considerations into account in the project selection process, set environmental targets, and develop ecodesign procedures that fit the characteristics of the development process.

Now on to the fun part of thanking the people who have supported and guided me in my research.

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Stockholm, February, 2006
Publications

Appended papers


Paper IV Ölundh, G. and Ritzén S. (Submitted for publication in a scientific journal) Setting Environmental Targets in Product Development.

Paper V Ölundh, G. and Tingström, J. (Submitted for publication in a scientific journal) Managing Radical Innovation and Environmental Challenges: Development of a Dry Capacitor at ABB.

Related publications


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1 Introduction

The focus of environmental work in manufacturing companies has increasingly shifted from end-of-pipe solutions to the environmental performance of products and services. The product development process is central to creating value for customers. This thesis argues that companies can simultaneously create value for consumers and be profitable while taking environmental considerations into account.

The goal of the Swedish government’s environmental policies is to solve the greatest environmental problems in our society within one generation and to reach a sustainable society (Prop. 2004/05:150). Ecodesign is one instrument that contributes to the attainment of that goal by contributing knowledge of how to develop innovative products and integrated solutions while taking environmental considerations into account.

Environmental issues are often closely linked with ethical decisions, for sustainability may require company leaders to make ethical decisions and not just economic ones (Schendler, 2002). In other words, leaders will have to accept that being green means that they will not always be able to make the most economical choice. Environmental considerations are thus closely connected to people’s personal beliefs, which are difficult to influence.

Another possible way of looking at things, however, is to argue that people must feel that environmental issues are important (Strannegård, 1998). When it comes to environmental issues, it is easy for people to say the politically correct thing, but in order to get things done, managers really have to feel that what has been said is important. Otherwise environmental initiatives may become no more than paper-tigers, looking aggressive but amounting to nothing more than a piece of paper. The feeling that environmental issues are important is not necessarily a moral feeling, and so it is necessary to provide incentives to encourage people to take environmental concerns seriously (Strannegård, 1998). There is thus a need to connect environmental concerns and business strategy.

Ecodesign is closely associated with business strategy since product development is a strategic activity. Business strategy has considerable influence on the environmental performance of products and services, for how environmental issues are viewed affects the weight given to environmental considerations in product development.

There are different views on how companies should consider environmental issues. Some researchers favour radical dematerialism and call for a new economy in order for the world’s companies to achieve sustainability (Ayres, 1996; Ayres, Geraldo and van

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1 ‘Ecodesign is the design of a product, service or system with the aim of minimising the overall impact on the environment’ – Sherwin and Evans (2000).
Leynseele, 1997). This would mean radically rethinking the business-as-usual approach (Dobers and Wolff, 1999). It would also require active strategic choices (Ulhoi, Madsen and Hildebrandt, 1996). Rethink strategies are becoming part of ecodesign since they affect how products and services are produced and delivered. This thesis studies rethink strategies as well as radical product development aiming for innovative products, which can be referred to as a redesign approach.

Rethink strategies can be one way of developing business opportunities while also taking environmental considerations into account. This combination is important since it is crucial that environmental considerations add value to consumers and shareholders (Reinhardt, 1999).

This thesis focuses on the early stages of the product development process. Which projects are selected for realization and how environmental targets are set are important components of successful ecodesign.

Ecodesign in manufacturing companies needs to be modernised. Ecodesign should help companies to make a profit without neglecting environmental considerations.

1.1 Objectives and research questions

Central to this thesis are redesign and rethink approaches in manufacturing companies. These approaches are linked to projects with high possibilities for influencing environmental performance. In redesign projects, radically new products are developed; in rethink approaches, the focus is on designing a totally new product, product functions or even new business concepts (Charter and Chick, 1997).

When developing new business concepts in manufacturing companies that show environmental concern, the focus often falls on developing and offering services (see, for example, Stahel, 1997; Brezet and van Hemel, 1997; Reinhardt, 1999; Zaring, 2001). New business concepts can be seen as integrated solutions where products and services are integrated into a market offer (Davies, 2003). In this thesis, products are seen as physical artefacts or software products.

Earlier research on the integration of environmental concerns in product development has been general in character. The focus is on how to achieve successful ecodesign. The integration approaches developed by for example Ritzén (2000); Cramer and Stevels (1997) and Simon et al. (2000) are useful for the contexts they studied. When modernising ecodesign, work procedures needs to be adjusted to fit redesign and rethink projects. Ecodesign activities in manufacturing companies are often of a corrective nature (Sherwin and Bhamra, 1999). In other words, ecodesign is often used to ensure that legal requirements are met by having environmental checkpoints in the development process. In this approach, ecodesign activities are more suited to dealing with incremental improvements then with innovative development processes (Sherwin and Bhamra, 1999). Ecodesign, however, should also promote and fit in with innovative development processes.
A limitation of the research is that it does not focus on technical aspects but rather on strategic considerations and the organisation of development processes.

The first research objective (RO) is related to the role of ecodesign in innovative development processes for projects with a high possibility of affecting environmental improvements.

The research questions (RQ) used in fulfilling the objective is focused on how ecodesign is performed in practice and how that could evolve to fit redesign and rethink projects.

RO 1 To explore and develop recommendations for how ecodesign can be modernised in manufacturing companies to fit redesign and rethink projects.

RQ 1 How is ecodesign undertaken in manufacturing companies when realising redesign and rethink projects?

RQ 2 What factors influence how ecodesign is undertaken in manufacturing companies in regard to redesign and rethink projects?

There are different views on which actors in the design process are crucial for successful ecodesign. Åkermark (2003) and Lindahl (2005), for example, suggest that the design engineers have a crucial role in minimising the environmental impact of products. Lofthouse (2004), on the other hand, argues that industrial designers have an important role in operational product development since they have a different perspective to design engineers and are involved earlier in the design process. She also points out that several tools for ecodesign have been developed for design engineers and may not be very well suited to industrial designers. These researchers, and many others like them, are focused on the operational stages of ecodesign.

Ecodesign is, however, also concerned with strategic issues. For example, Cramer (2000) argues that environmental aspects need to be integrated in the very early stages of product development, such as the idea stage, prior to defining product targets. Simon et al. (2000) state that setting early priorities is the most critical factor for successful ecodesign. Sherwin and Bhamra (1999) also argue that in order to get maximum environmental benefits from products, we need to integrate environmental considerations as early as possible in design, when developing the project brief or generating ideas. Such an approach could enable ecodesign to move from being corrective in character to influencing more innovative solutions and active environmental work in firms.

The second research objective was rooted in the conclusions drawn from academic studies, namely that successful ecodesign needs to have a clear direction and that environmental targets should be set early on in the product development process. Setting the target specification for a project is an important activity affecting the
environmental performance of products. An underlying assumption here is that if environmental considerations are only taken into account once the specification for a product has already been set, the design possibilities will be limited (Bhamra et al., 1999; Poole et al., 1999). In the later stages of a project, there is less design freedom and the cost of making changes is higher (Ullman, 1997). The importance of environmental targets is often stressed, though little research has been done on how environmental targets are actually set in industry. The research questions were selected to clarify how project selection and environmental target setting are performed in industry.

RO 2 To explore and to develop recommendations for how manufacturing companies can take environmental considerations into account in the early stages of the product development process.

RQ 3 Do manufacturing companies take environmental considerations into account when selecting product development projects, and if so, how is this done?

RQ 4 How are environmental targets set during product development in manufacturing companies, and what are the advantages and disadvantages of different procedures?
2 Theoretical framework

Ecodesign is a young research field that has developed over the last few decades. Thus researchers often treat it as a new subject and do not take existing product development theory or practice as their point of departure (Baumann, Boons and Bragd, 2002). Researchers investigating how to integrate environmental concerns in product development and business, however, benefit from using dedicated traditional theories in regard to innovation, product development and organisational theory (see, for example, Andersson and Wolff, 1996; Wolff, 1998; Magnusson, 2003; Strannegård, 1998). Ecodesign research would also benefit from treating environmental concerns and demands as a design and business problem (Berchicci and Bodewes, 2005). This thesis thus considers influences from other research field. It does not claim to provide full coverage of the literature in these fields, but rather seeks to influence and extend ecodesign research using knowledge from other research fields.

The theoretical framework presented here lays the theoretical foundation for the research that follows and is also intended to give readers an understanding of the research objectives. Ecodesign theory is combined with theory from other fields relating to setting product targets and selecting project portfolios (see Figure 2.1). Theory on product development and innovation management is also used, as well as theory on how to manage rethink approaches (for example, theory from research on integrated solutions).

An overview is also given of different environmental ambition levels and activities that lead to improved environmental performance of products, as well as of the integration of ecodesign into the product development process.

Figure 2.1 Illustration of theory fields used for understanding ecodesign, besides ecodesign literature.
Theoretical framework

2.1 Definition of ecodesign

The field of ecodesign is also called design for the environment. Research on ecodesign is largely focused on how to systematically integrate environmental considerations in the development of products, services and systems. Because the research field of ecodesign is still evolving, different researchers are constantly redefining the view of what ecodesign is. A few definitions are presented here, the last of which is used in this thesis.

One definition of ecodesign is: ‘Ecodesign considers environmental aspects at all stages of the product development process, striving for products that make the lowest possible impact throughout the product life-cycle’ (Brezet and van Hemel, 1997). In this definition, it is the physical artefact that is the focus of ecodesign.

Simon et al. (2000) take a broader perspective and also include services in their definition of ecodesign: Ecodesign is a broad term implying a balanced view of the whole product life cycle and design effort focused on reducing the major environmental impacts of a product or service.

What both these definitions have in common is that they address environmental impact throughout the whole life-cycle, including production, use and end-of-life, which is important in order to see the total environmental impact of products.

Sherwin and Evans (2000) define ecodesign as the design of a product, service or system with the aim of minimising the overall impact on the environment’. They argue that ecodesign is eco-product development and refers to integration of environmental considerations at all stages of the product development process. They also incorporate the development of systems in their definition. This definition, which includes products, services and systems, will be the one used in this thesis.

2.2 Environmental ambition levels

Eco-efficiency and dematerialisation are different environmental ambition levels. Both terms are often used in the literature when discussing the effects of different ecodesign activities. Dematerialisation is particularly prominent in discussions of increasing the service content in offers to consumers (see, for example, Hekkert, van der Pas and Treffers, 2001; Dobers and Wolff, 1999; Heiskanen et al., 2001).


The WBCSD defines eco-efficiency as ‘being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth’s estimated carrying capacity.’
Theoretical framework

The Council has identified four aspects of eco-efficiency that make it an indispensable strategic element in today's knowledge-based economy (www.wbcsd.ch):

- ‘De-materialisation: Companies are developing ways of substituting knowledge flows for material flows
- Closing production loops: The biological designs of nature provide a role model for sustainability
- Service extension: We are moving from a supply-driven economy to a demand-driven economy
- Functional extension: Companies are manufacturing smarter products with new and enhanced functionality and selling services to enhance the products’ functional value.

The WBCSD considers dematerialisation to be part of eco-efficiency. Dobers and Wolff (1999), however, draw attention to differences between the two terms. Dematerialisation focuses on the input side of material and energy use, whereas eco-efficiency focuses on the output side of material and energy use (Dobers and Wolff, 1999). Eco-efficiency is often referred to as ‘doing things right’, meaning that the environmental impact per functional unit is reduced. Focusing on input orientation, as dematerialisation does, has the effect of avoiding introducing material into the societal loop by reducing the overall amount of materials and energy used.

Heiskanen and Jalas (2000) argue that the discussion of services and dematerialisation is confusing. The discussion takes place at two levels. The first is the macro-economic level, at which authors such as Stahel (1997) promote a functional economy, which he defines as ‘one that optimises the use (or function) of goods and services and thus the management of existing wealth (goods, knowledge, and nature)’. Services are increasing in society, and it is thus possible to dematerialise the creation of value for consumers. The other level of discussion focuses on business strategy, arguing that companies should create value for consumers through adopting a less material- and energy-intensive approach. One way of doing this is by providing services. Businesses thus have to rethink how they create value for consumers.

2.2.1 Product development and environmental benefits

The literature on ecodesign often calls for higher levels of innovation in order to achieve environmental benefits (see, for example, Sherwin and Bhamra, 1999). Innovation levels are often divided into categories on the basis of the scope of the possibilities for achieving environmental benefits. Charter and Chick (1997) describe a four-stage model for environmental benefits, using the categories Repair, Refine, Redesign and Rethink (see Figure 2.2). Their approach is adopted in this thesis to distinguish different approaches to ecodesign when there are different possibilities for environmental improvements and different types of product development projects. This four-step model is widely used in ecodesign literature.

The four stages move incrementally from making small changes in a product to totally redesigning the product or business systems. Repair of a product focuses on solving emergency problems. Refine focuses on achieving eco-efficiency in products. Redesign
focuses on reaching a state where environmental factors are incorporated from the start and fundamentally change the design of the product. Rethink, the last stage, focuses on designing a totally new product, new product functions or new business concepts. One of the strategies that can be applied at this stage is dematerialisation, in which products are substituted with services. Moving from the redesign stage to the rethink stage requires significant leaps in thinking, according to Charter and Chick. For example, attention will have to be paid to cyclic material loops. Heiskinen and Jalas (2000) also argue that the shift that is called for involves social innovation as well as product innovation, for there is more of a need to influence consumer behaviour than there is when simply developing a new product.

The Charter and Chick model has been used to show that the approach to product development in leading-edge companies concentrates on the lower steps in the model, which have less potential for environmental benefits. Over time, companies need to focus more on redesign and rethink strategies. In rethink strategies, the business strategy is also affected by ecodesign activities and environmental work is shifted from being focused on products and becomes embedded in business solutions (Stevels, 2001).

Figure 2.2  A four-step model of approaches to environmental improvements in product development (Charter and Chick, 1997).

Sherwin and Evans (2000) claim that the type of design activity and the product development characteristics affect when to perform ecodesign. Thus when attempting radical product redesign and rethinking, ecodesign needs to be integrated at the early stages of product development. When a project is focused on an area where there are fewer options, such as when arranging for product disassembly, the avoidance of toxic materials and energy efficiency, ecodesign could be integrated at later stages.
2.3 Activities that improve the environmental performance of products

The definition of ecodesign makes it clear that it is important to consider the whole life cycle of products and services. Brezet and van Hemel (1997) summarise the strategies that companies can use during different stages of a product’s life cycle in order to lower its environmental impact.

The eco-strategy wheel is illustrated in Figure 2.3. By adopting a particular strategy, a company is choosing to target a particular aspect of a product’s life cycle. The choice can range from one affecting the materials used to one involving the development of a new product concept that will also have an impact on the business strategy. Strategies for ecodesign can focus on material selection and chemical substances, energy consumption and size and weight issues connected to the product. End-of-life aspects are also part of ecodesign, as are remanufacturing issues. A different ecodesign strategy is to develop new business strategies. For example, leasing or functional sales could lead to dematerialisation or shared use of products.

Companies’ attempts to lower the environmental load can be categorised in terms of the areas on which they focus. The categories are associated with energy consumption, the amount and type of material used, and how products and parts are packed and transported. The durability and recyclability of products are of concern, as also is whether toxic substances are used. The objective is to lower the environmental impact over the product’s life cycle, including the raw materials used to create it, the environmental load when it is in use, and end-of-life aspects.

Baumann et al. (2002) identified more than 150 means of dealing with environmental issues during the product development process. The tools varied from simple checklists to sophisticated computer-based expert systems, and included technical strategies such as material substitution or dematerialisation. Most of them were intended to be used in the product development process. But, as Baumann et al. (2002) and Lindahl (2005) point out, although there are numerous methods and tools, few are actually being used in industry.
2.4 The product development process

This section of this thesis offers a brief introduction to the product development process, which is a set of company activities for transforming an idea into a realized product. According to Ulrich and Eppinger (2004), product development can be defined as ‘the set of activities beginning with the perception of a market opportunity and ending with the production, sale, and delivery of a product’.
Product development is a business-oriented activity. The environmental strategy in a company is connected to the company’s corporate mission, and the business strategy reflects the product development strategy (Keldman Hansen, 1997), see Figure 2.4. The business perspective is also reflected in the ecodesign work.

![Image](https://example.com/image.png)

**Figure 2.4 Product development in the planning structure with flows of information formalised by environmental management systems (Keldman Hansen, 1997).**

Product development activities can be more or less structured, and several formalised product development processes have been developed. Ulrich and Eppinger (2004) state that a well-defined product development model helps to ensure the quality of products, and facilitates the coordinating and planning of product development, the managing and identification of possible problem areas, and the identifying of improvement areas through careful documentation. In the manufacturing industry it is common for larger companies to have formal product development processes. Different models focus on different aspects of product development, such as integration between different functions involved in the process, go/no-go decisions, and when to perform what activities. The models are based on the development of physical products.

A generic development process is illustrated by Ulrich and Eppinger (2004), see Figure 2.5. The planning stage is business-related and includes market investigation, financing and overarching technical considerations. It determines the assumptions and constraints
that guide the development effort. Ulrich and Eppinger (2004) point out that one of the factors guiding the direction of the project at this stage is the environmental ambition level. This ambition may be expressed in a target specification. This process ends with a project selection process. Once a project has been selected, the concept development phase starts. Different solutions to technical problems are tested and evaluated before one concept is realized. The process then moves on to more and more detailed design and testing of products before the product is put into production.

![Planning Concept System-Level Design Detail Testing and Refinement Production Ramp-Up](image)

Figure 2.5 A generic product development process (Ulrich and Eppinger, 2004).

Stage gate models are common in large manufacturing companies. A stage gate model is divided into activity phases within which work is performed with the goal of developing a product. Located between the activity phases are important decision points or ‘gates’ (Cooper, 1988). At these decision points, it is decided whether or not the development of the product should proceed. For example, the process starts with a generation and screening of ideas in order to develop design concepts. The concepts are then investigated and a ‘go or no go’ decision is taken before developing each product.

At the same time as the formalised product development process is being followed, there must be parallel activities relating to marketing, design and production (Andreasen and Hein (1987). Such parallelism shortens the product development cycle. Wheelwright and Clark (1992) have concluded that it is beneficial to adopt an integrated approach to product development, meaning that people with different knowledge and roles work together in product development. For example, marketing, product development and production need to interact for successful product development. Norell (1999) states that multifunctional teams provide a basis for integrated product development.
2.5 Models for integrating ecodesign in the product development process

Integrating ecodesign into product development enables companies to lower the environmental impact of their products. Ecodesign activities affect all aspects of the product development process and thus need to be incorporated at all stages.

Ritzén (2000) recommends proactive measures for integration of environmental aspects (see Figure 2.6). She concludes that it is important to set the direction for the environmental work and to prioritise environmental aspects both at the business level and in product development. If the environmental approach is to be sustained, it also important to create individual commitment to accepting changes such as developing environmental knowledge, using support tools and changing work procedures to incorporate ecodesign. The driving forces can be seen as fuel for the environmental work.

One of the early methodologies that were developed is known as STRETCH (Selection of Strategic Environmental Challenges). It consists of the following five steps (Cramer and Stevels, 1997):

1. Identify crucial driving forces that influence the business strategy.
2. Develop scenarios that the company can adopt based on the driving forces and develop a list of potential product market strategies.
3. Specify potential environmental opportunities and threats for each scenario.
4. Select environmental challenges that will lead to substantial improvements in the environmental performance of products.
5. Implement the environmental challenges selected.

A key ingredient in this model is the development of different scenarios that could lead to potential product strategies. The environmental work builds on these scenarios.
Simon et al. (2000) developed a framework for ecodesign strategy and action (Table 2.1). They also acknowledge the need to work at both a strategic and an operational level in order to achieve successful ecodesign. They suggest that the first step is to **analyse** the drivers for ecodesign and to analyse the product from a life-cycle perspective. The results of this analysis must then be **reported**, so that information about environmental implications and performance is communicated both within and outside the company. Environmental issues need to be **prioritised** and an ecodesign strategy set up, as well as environmental targets for products. There is also need to **improve** the work processes in the company.

**Table 2.1 The APRI (Analyse, Report, Prioritise, Improve) framework (Simon et al., 2000).**

<table>
<thead>
<tr>
<th>Step</th>
<th>Strategic level</th>
<th>Operational level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyse</td>
<td>Assess the external and internal drivers for ecodesign and benchmark the organisation</td>
<td>Assess the product in the light of specific drivers, using LCA or similar tools</td>
</tr>
<tr>
<td>Report</td>
<td>Communicate the corporate environmental status and policy to improve environmental culture</td>
<td>Communicate the results to the design team and obtain feedback</td>
</tr>
<tr>
<td>Prioritise</td>
<td>Develop an ecodesign strategy (within the corporate product development strategy) and set overall ecodesign objectives</td>
<td>Set targets for the product for inclusion in the specification; targets may be chosen levels for company metrics</td>
</tr>
<tr>
<td>Improve</td>
<td>Plan action such as pilot projects and training; develop or customise metrics, tools and methods</td>
<td>Carry out normal product design incorporating appropriate tools used by trained and aware designers</td>
</tr>
</tbody>
</table>

When integrating ecodesign in the whole product development process, both operational and strategic activities need to be considered. It is also important to consider the maturity level of the company in order to find the right level of ecodesign work and further develop the work. The activities needed for successful ecodesign are usually not ranked, but are presented as part of the big picture. It is use of all the factors together that creates successful ecodesign. However, when some attempt is made to rank factors, prioritising and setting direction are crucial factors (Simon et al., 2000). Sufficient driving forces are needed to fuel for the environmental work (Ritzén, 2000). Handling environmental information is considered to be the most important issue in another study (Boks and Pascual, 2004). Tailor-made tools for the company needs, checkpoints and the support and commitment of management are also considered crucial.

**2.5.1 Ecodesign maturity**

McAloone (2000) claims that the practice of ecodesign matures as a company undergoes the four-step transition from 1) simply designing to 2) gaining environmentally conscious design motivation to 3) learning how to develop and communicate environmentally conscious design ideas to 4) taking a whole-life view of its products.
He claims that whole-life thinking in design occurs in companies that have widespread support for environmentally conscious design and a high level of motivation. A company that takes a whole-life perspective understands the possible trade-offs between environmental costs in different phases of the product life cycle, and recognises that environmental improvements can be economically beneficial. McAloone (2000) suggests that such thinking can lead companies to redefine their core business by increasing the service content in their sales offers, as advocated in rethink approaches (see Charter and Chick, 1997).

Johansson (2001) argues that innovative ecodesign represents an even higher level of ecodesign maturity. In innovative ecodesign, the focus is on using technology and technical problem-solving to develop radically new designs rather than on using ecodesign tools in product development. There is more interest in the environmental result of innovative development projects than on simply using ecodesign tools in the development process.

2.6 Early stages of product development

To better understand the early stages of ecodesign, one must first understand both ecodesign and the early stages of product development (Sherwin and Evans, 2000). Since the second research objective (RO2) is focused on these stages, an introduction is now given to project portfolio selection activities and how project and product targets are set.

2.6.1 Project portfolio selection

For product development to be successful, a company must develop the right product. One way a company can do this is by applying project portfolio management, that is, by having a structured process for selecting the right product development projects. Correct project selection is very important for the competitiveness of a company and for the environmental performance of products. This step in the product development process has been little researched from an environmental perspective, yet the projects chosen affect the environmental performance of a company.

Portfolio management is a dynamic process for evaluating, selecting and prioritising new projects and comparing proposed projects with existing ones (Cooper, Edgett and Kleinschmidt, 2001). Cooper et al. identify four major goals of portfolio management:

- **Maximise the value of the portfolio.**
- **Strategically align the portfolio** to ensure that the portfolio reflects the company’s business strategy.
- **Balance the portfolio** to ensure that it has the right mix of projects. There needs to be a balance between long-term and short-term projects, high-risk and low-risk projects, and various markets and technologies.
- **Have the right number of projects** because companies have limited resources and can only handle a certain number of projects at the same time.

Project portfolio selection involves several steps with several screening gates. A large number of ideas are evaluated using different screening processes, and only a few of
Theoretical framework

them survive to become realized product development projects. Wheelwright and Clark (1992) illustrate this with a funnel where product development ideas are evaluated at different gates between different phases (see Figure 2.7).

Figure 2.7 Development funnel model (Wheelwright and Clark, 1992).

Archer and Ghasemzadeh (1999) describe the process of handling project portfolio management in terms of different activities (see Figure 2.8). First, there is the collection of ideas and proposals for new products. These ideas are then evaluated in a prescreening, and those that survive this screening undergo deeper analysis. Thereafter the project ideas are compared with existing projects in order to balance the project portfolio.

Figure 2.8 Activities in project portfolio management (Archer and Ghasemzadeh, 1999)

Thus the ideas for product development projects are evaluated in various screening activities and narrowed down to a few that actually become product development projects.

The screening activities in portfolio management can be compared with a stage-gate process (Cooper et al. 2001). When integrating portfolio management into the stage-gate process, ideas are evaluated individually for a pass/kill decision and are also compared with existing projects for a go/hold decision. The project ideas undergo detailed investigation, during which the product definitions and project plans are defined before the screening on a business case is done.

2.6.2 Setting product targets

The product specifications, which include the design requirements, play an important role in product development. The design requirements have two principal roles: 1) they serve as an agreement about what is desired in the end product, and 2) they provide the basis upon which the engineer can proceed when developing a solution (Darlington and Cully, 2004). They thus represent both a contract between management and operational product development and a guide for project leaders and engineers in the development
Theoretical framework

process. The activities leading to a product specification are important parts of ecodesign, for they involve setting environmental targets.

Ulrich and Eppinger (2004) define specifications as follows:

‘Specifications provide a precise description of what a product has to do. They are a translation of the customer needs\(^2\) into technical terms. Targets for the specifications are set early in the process and represent the hopes of the design teams. Later these specifications are refined with the constraints imposed by the team’s choice of a product concept.’

In an ideal world, the product specifications are set only once early on in the design process (Ulrich and Eppinger, 2004). However, this is rarely possible for technology intensive products. For such products, the specifications are set at least twice. The first specification is strategic, and involves a general target specification set after the first planning stage. From an ecodesign perspective, this is a very important stage for setting environmental targets. However, this target is specified before the constraints for the product technology are known. Thus the specification is refined and revised during the operational development, once a product concept has been chosen. Difficult trade-offs have to be made between different desirable characteristics in order to reach the final specification. Some specifications may be revisited many times during the development process. If this is not done, and there is no flexibility in the approach, a determined effort to fulfil often incomplete and conflicting requirements may result in sub-optimisation and project stagnation (Almefelt, Andersson, Nilsson and Malmqvist, 2003).

Several actors are involved in the target-setting process. The first target specification is set prior to the development of concepts. At this stage, strategic planners and marketers are heavily involved in the target-setting process. Rather than being explicitly methodology-based, the development activity is characterised by a responsive ad hoc approach (Darlington and Cully, 2004).

Bragd (2002) attempted to outline the balancing process involved in setting targets. In this process, the company has to deal with conflicting demands and ambition levels that are dictated by the technology and core values, while simultaneously remaining tuned in to customer values. Environmental aspects of the project also have to be dealt with as part of this process, and they are in competition with all the other considerations. Bragd argues that the balancing process is highly arbitrary. Even though it takes place within a structure of normative reasoning, it boils down to who has the best bargaining power and can thus get their specifications included in the target.

\(^2\) There is some debate on whether specifications should be written using the voice of the customer or the technological opportunities within the company. Cooper (1999), for example, proposes that a company should have a slave-like dedication to the customer’s expressed needs. Utterback (1994), on the other hand, argues that when it comes to achieving radical innovation, one should not pay too much attention to the customers’ expressed needs Customers may not know what they need, nor what can be achieved with a certain technology.
Environmental management systems and product targets

Environmental management systems (EMS) guide companies on how to organise environmental work and set out the requirements that companies should meet in order to be able to be registered by getting a third party audit of the EMS. ISO 14001 is an example of a standardised EMS system. Among the requirements is having an environmental policy and analysing the environmental impact of the company. This analysis should identify the significant environmental aspects that the company needs to work on. The company should then work towards continuous improvements in lowering the identified environmental load. An EMS can also guide a company in setting environmental targets for products by identifying the products as significant aspects of the environmental performance of the organisation. However, EMS focus mainly on site-related environmental impacts.

Ammenberg and Sundin (literature review 2005a, empirical study 2005b) have studied how environmental management systems and product-oriented management systems (POEMS) affect ecodesign. Their literature review reveals that the results are varied. Some researchers consider that EMS and ecodesign are well integrated, while others consider the link to be weak. The ISO 14001 requirements and recommendations do refer to products and services, but there is no emphasis on product development and much room for interpretation. Also the fact that the main focus in EMS falls on site-specific issues means that products are not usually identified as having a significant environmental impact, and thus they are not prioritised. Ammenberg and Sundin do, however, conclude that the studies they review show varied results. They suggest that EMS may be useful for making ecodesign efforts permanent, on the basis of the continuously improvement cycle used in EMS.

POEMS focuses on product development and comprises the following steps (Ammenberg and Sundin, 2005a):

1. Product-specific environmental review
   a. Identification of environmental impacts/aspects
   b. Review of Ecodesign, organisation and capabilities
   c. Review of the product development process
   d. Market investigation
2. Responsibilities and procedures
   a. Definition of roles, responsibilities and authorities for product development
   b. Establishment of policies, objectives and targets
   c. Revision of product development process
   d. Establishment of procedures for staff involved in product development and other product-related activities
3. Ecodesign projects
   a. Development of environmentally compatible products with competitive price, performance and quality standards
4. Audit/Evaluation
   a. Revision of existing procedures and products aiming for continual improvement
2.7 Development processes for radical projects

Incremental innovations involve only small steps within a technology, as illustrated by the S-curve in Figure 2.9. Radical innovation involves large steps and technology changes, but is vital to redesign of products. It is represented by the shift from technology 1 to technology 2.

Verzyer (1998) argues that radical product development projects need to be handled differently than incremental product development. He found that radical projects showed a consistent pattern that differed from traditional models. McDermott (1999) also looked at radical innovation project and argues that they demonstrate a set of challenges and managerial approaches that are different from those used in incremental innovation projects. The characteristics of radical innovation projects are summarised in Table 2.2. These findings suggest that a strong project champion is important and that formalised stage gate processes are unsuitable for radical projects. A strong project champion is even more important when it is difficult to follow a formalised process in realize the project, and when uncertainty creates a need for an exploratory and iterative work process. Having a broad network inside and outside the company is important. Fortuitousness also played an important part in moving the projects forward.
Table 2.2 Characteristics of radical innovation projects.

<table>
<thead>
<tr>
<th>Characteristics of Radical Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project champion</strong></td>
</tr>
<tr>
<td>The projects originated decades ago, in the 1960s and 1970s and had all been eliminated at least once (McDermott, 1999). Strong project champions with a vision for the product and drive to advance the development were important (Verzyer, 1998). If there had not been a project sponsor, they would not have been realized (McDermott, 1999).</td>
</tr>
<tr>
<td><strong>Formalised stage-gate process unsuitable</strong></td>
</tr>
<tr>
<td>Formalised stage-gate processes were not suitable for projects characterised by intensive technology development (Verzyer, 1998).</td>
</tr>
<tr>
<td><strong>Uncertainty</strong></td>
</tr>
<tr>
<td>The projects have high degree of uncertainty, both as regards the market and the technology (Verzyer, 1998).</td>
</tr>
<tr>
<td><strong>Exploratory</strong></td>
</tr>
<tr>
<td>The development processes were more exploratory and less customer driven (Verzyer, 1998).</td>
</tr>
<tr>
<td><strong>Fortuitousness</strong></td>
</tr>
<tr>
<td>The projects were messy and coincidence and fortuitousness played an important role (Verzyer, 1998). All projects included events that could be characterised as ‘random’. For example, a conversation with a customer or an accident in the lab advanced the project (McDermott, 1999).</td>
</tr>
<tr>
<td><strong>Iterative</strong></td>
</tr>
<tr>
<td><strong>Networks</strong></td>
</tr>
<tr>
<td>Informal networks inside and outside the company were important (McDermott, 1999).</td>
</tr>
<tr>
<td><strong>Early phases</strong></td>
</tr>
<tr>
<td>Early design and prototyping were an essential part of the development processes (Verzyer, 1998).</td>
</tr>
</tbody>
</table>

Eisenhardt and Tabrizi (1995) argue that traditional theories are inadequate to describe companies in fast-changing competitive settings. They propose a dynamic theory that captures the need for being adaptive to the situation in the company. A compression model and an experiential model are proposed. Hjelm and Berggren (2001) interpreted that the compression model is suitable for fast product development projects in mature industries with not-too-complicated technological problems, components and subsystems, especially geographically distributed development. The experiential model is suitable for products with high technological and commercial uncertainty.

An underlying assumption of the compression strategy is that product development is a process that can be planned in a series of discrete steps (Eisenhardt and Tabrizi, 1995). The process can be shortened by shortening each step in the process or overlapping steps. In order to have overlapping steps, multifunctional teams are important.

The experiential strategy concludes that it is unrealistic to shorten product development time by only compressing the process (Eisenhardt and Tabrizi, 1995). The underlying assumption is that product development is a highly uncertain process involving foggy and shifting markets and technologies. Although structure is still important to create
stability and maintain pace, rely on intuitions, have flexibility in the organisation, rapid learning and adapting to uncertain environments are crucial. The experiential strategy fits well with the characteristics listed in Table 2.2.

Magnusson (2003) states that when managing radical environmental innovation, it is very important to master complexity. His managerial suggestions are focused on projects where challenging environmental targets have already been set. He suggests three managerial approaches for dealing with different type of complexities.

- **Simplification** involves reducing the complexity of the environmental issues and understanding the environmental impact of products. One way in which this can be done is by using tools and methods for environmental assessment. The development task can also be simplified, for example, by focusing only on solving the technical aspects and leaving such things as the cost of manufacturing to be dealt with in a subsequent project.

- **Interaction** involves co-ordination. This can be addressed in different ways, including collocation and developing routines for horizontal communication. Integration is also needed with actors outside the R & D department, including equipment manufacturers, authorities and marketers.

- **Experimentation** involves extensive prototyping and testing in order to solve technical problems.

### 2.8 Business strategies for rethink approaches

Sections 2.1 and 2.2 spoke of companies rethinking business strategies and developing new business concepts in order to achieve dematerialisation. Reinhardt (1999) also promoted *redefining markets* as a strategy for firms to use in order to improve their environmental performance and profitability. One example that is often used to illustrate what it means to redefine or rethink a business model by finding new business opportunities is Xerox. Instead of selling photocopiers, Xerox sells the possibility of making copies and retains ownership of the machines. This approach means rethinking the notion of property rights. Definitions of various concepts are given in Table 2.3.

Several concepts have emerged for describing business strategies that also take environmental considerations into account. While these concepts are similar, each highlights a different aspect. White, Stoughton and Feng (1999) summarise what the concepts are about by declaring that *servicising* is ‘the emergence of product-based services which blur the distinction between manufacturing and traditional service sector’.
Table 2.3 Definitions for different rethink business concepts.

<table>
<thead>
<tr>
<th>Business concepts</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional Sales (FS)</strong></td>
<td>‘to offer from a life-cycle-perspective a functional solution that fulfils a defined customer need. The focus is, with reference to the customer value, to optimise the functional solution from a life-cycle perspective. The functional solution can consist of combinations of systems, objects and services.’ (Lindahl and Ölundh, 2001)</td>
</tr>
<tr>
<td>(Abrahamsson and Eriksson, 1997; IVA, 2000; Lindahl and Ölundh, 2001; Ölundh, 2003; Söderström, 2003)</td>
<td></td>
</tr>
<tr>
<td><strong>Integrated solutions</strong></td>
<td>Adding value and bringing together products, systems and services. Complete business solutions, which involve the integration of products and services. (Davies, 2003).</td>
</tr>
<tr>
<td><strong>Service Engineering</strong></td>
<td>Service engineering deals with services in an engineering manner. ‘We need to intensify service contents within a product life cycle or a value chain for dematerialization’. (Tomiyama, 2001)</td>
</tr>
<tr>
<td>(Tomiyama, 2001)</td>
<td></td>
</tr>
<tr>
<td><strong>Eco-efficient services (EES)</strong></td>
<td>‘Eco-efficient services are all kinds of commercial market offers aimed at fulfilling customer needs by selling the utilisation of a product (system) instead of providing just the hardware for these needs. Eco-efficient services are services, related to any kind of hardware, of which some of the properties rights are kept by the supplier.’ (Meijkamp, 2001)</td>
</tr>
<tr>
<td>(Hockerts, 1998; Meijkamp 2001)</td>
<td></td>
</tr>
<tr>
<td><strong>Eco-efficient producer services</strong></td>
<td>‘An eco-efficient producer service is one which improves the eco-efficiency of customer activities. This can be done directly (by replacing an alternative product-service mix) or indirectly (by influencing customer activities to become more eco-efficient.’ (Zaring, 2001)</td>
</tr>
<tr>
<td>(Zaring, 2001)</td>
<td></td>
</tr>
<tr>
<td><strong>Product Service Systems (PSS)</strong></td>
<td>‘A system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and has a lower environmental impact than traditional business models’ (Mont, 2004)</td>
</tr>
<tr>
<td>(Goedkoop et al., 1999; Mont 2001, 2004)</td>
<td></td>
</tr>
</tbody>
</table>

The functional sales (FS) concept emphasises that the focus needs to be on creating value for consumers by selling services or functions, thus shifting the transaction from selling goods to selling performance, function or service. This approach has emerged from a business perspective and its environmental possibilities have already been acknowledged. Eco-efficient services (EES), like functional sales, highlight the point that the ownership of products is not transferred to the user of the product. However, the environmental aspects are more prominent. Eco-efficient services focus on creating new business alternatives that can replace existing solutions with an alternative product-
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service mix and also on consultancy-like services to improve environmental performance. **Product service systems** (PSS) is the concept that places the highest demands on a system.

According to Mont (2004), PSS contains the following main elements:

1. Products, services or combinations of them
2. Services offered at the point of sale, including financial services and customer training in product usage
3. Product use concepts such as use or result-orientation
4. Maintenance services for extending product life
5. Revalorisation services for closing material loops by taking back products, reusing and recycling materials

Mont (2004) considers that the other concepts often only cover some of the elements needed in a PSS system.

**Integrated solutions** do not specifically focus on environmental aspects but rather on business and organisational aspects. The phenomenon studied is, however, the same as those studied by more environmentally oriented researchers – namely, that manufacturing firms are providing an increasing range of services (Davies, 2003). Integrated solutions involve combining products and systems with services in order to specify, design, deliver, finance, maintain, support and operate a system throughout its life-cycle (Brady, Davies and Gann, 2004). The focus is shifting from finding as many products as possible for a customer to packaging the right combination of products and services in offerings suited to customer needs (Galbraith, 2002). In a product portfolio, products and services need to be able to work together as an integrated system. Windahl et al. (2004) highlight the value of customer interaction and tailor-made solutions, but customisation needs to be combined with well-defined modular structures to achieve economies of scale at the component level.

Firms can move up or down the value stream in order to provide integrated services. Thus manufacturing firms are providing an increasing range of services, and service firms are beginning to take responsibility for the design and delivery of products (Davies, 2003).

In service engineering it assumed that service design has its conceptual design stage, where realization means are found for the goals as in traditional product design (Shimomura and Sakao, 2004). They have developed a service model called service explorer, a computerised tool for modelling services. One of the goals with service engineering is to develop a service CAD.

**2.8.1 Environmental effects of rethink approaches**

Goedkoop et al. (1999) claimed that with an attractive economic value of rethink approaches, the potential exists for unlinking environmental pressure from economic growth. A number of authors have discussed the potential for de-linking economic growth from the use of natural resources when providers offer services instead of
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products. Meijkamp (2001) and Heiskinen et al. (2001) questioned whether servicizing helped to disconnect economic growth from growth in environmental effects and do not see this de-linking as strong.

Reiskin et al. (2000) described one example where a new relationship to the customer can change the link between resource use and economic profit (see Figure 2.10). This example concerns chemical management services, where the supplier takes over chemical management from the chemical user and therefore becomes a service provider. In the traditional relationship, the supplier benefits from the volume of chemicals sold, but in the new relationship the service provider benefits from using a smaller amount of chemicals as the costs for the chemicals are internalised. The authors highlighted though, that this is an opportunity and not a guaranty for environmental benefits (ibid).

![Figure 2.10](image-url)

*Figure 2.10  Different relationships between provider and buyer in sales activities of a more traditional or product-based type (left) and a service-based type (right), (after Reiskin et al, 2000).*

Services and products are used to fulfil customer needs, and all require some kind of material, either directly or indirectly. The relation between the service content needed and the material content needed to fulfil customer needs varies. There are different kinds of EES, and a number of authors have used the categorisation presented in below.
**Table 2.4 Categorisation of eco-efficient services.**

<table>
<thead>
<tr>
<th>Service type</th>
<th>Description of service</th>
<th>Aspects countering positive environmental effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product-life extension services</strong> (Meijkamp, 2001)</td>
<td>Increasing the useful life of products or materials by maintenance, repair, reuse and recycling.</td>
<td>The reuse of products and their component parts is limited, while the recycling of material is more widespread. Take-back systems often require long transportation distances. Rapid replacement of products may occur. Hekkert et al. (2001)</td>
</tr>
<tr>
<td><strong>Product-orientation services</strong> (Hockerts, 1998).</td>
<td>Increasing the useful life of products or materials by maintenance, repair, reuse and recycling. Plus helping customers to optimise the application of a product through training and consulting.</td>
<td></td>
</tr>
<tr>
<td><strong>Product-use services or shared utilisation services</strong> (Meijkamp, 2001)</td>
<td>Increasing utilisation by sharing of products. Selling the use of a product. Vehicle leasing and car-pooling are examples.</td>
<td>Changing consumer habits is difficult, and ownership of for example a car is directly related to emotions and status. Hekkert et al. (2001); Meijkamp (2001). Cooper and Evans (2000) state there should be no option of final purchase of the product so that the responsibility for the product always stays with the provider.</td>
</tr>
<tr>
<td><strong>Use-oriented services</strong> (Hockerts, 1998).</td>
<td>Selling the use of a product. Vehicle leasing and car-pooling are examples.</td>
<td></td>
</tr>
<tr>
<td><strong>Result services</strong> (Meijkamp, 2001; Hockerts, 1998).</td>
<td>Selling a result instead of a product; for example, selling clean clothes instead of a washing machine. Selling a result instead of a product; for example, selling clean clothes instead of a washing machine. Selling a result instead of a product; for example, selling clean clothes instead of a washing machine.</td>
<td>Hekkert et al. (2001) only expected incremental environmental improvements from adopting result services. This is because these services stimulate good “housekeeping”, such as the reduction of production losses and the inclusion of other efficiency measures during the consumption stage. Innovation is focused on organizational and legal aspects rather than technical ones.</td>
</tr>
<tr>
<td><strong>Need-oriented services</strong> (Hockerts, 1998).</td>
<td>Satisfying customers regardless of the material product, where the provider guarantees a certain result.</td>
<td></td>
</tr>
</tbody>
</table>

These services range from offering maintenance and recycling, through offering leasing or sharing of products, to taking full responsibility for fulfilling a function, regardless of the products used – when the result is what is being offered.
FS fits into the EES categories, for its price-setting is value based and ownership is not transferred to the user in the EES. FS as a business strategy was not, however, originally developed with a view to reducing negative environmental impacts.

Ehrenfeld and Brezet (2001) claim that too much focus has been placed on increasing the content of service in sales offers to customers as a way of improving environmental performance (see Table 2.5). They suggest that people seek satisfaction using various means, which can be fulfilled by services or by products. What is important is finding sustainable satisfaction delivery systems, and not the issue of whether we should or should not produce certain services or products. Rather we should be identifying the innovative potential in the product, the infrastructure and the user.

Table 2.5 Characteristics that define innovative categories (after Ehrenfelt and Brezet, 2001).

<table>
<thead>
<tr>
<th>Level</th>
<th>Change in device concept</th>
<th>Change in infrastructure</th>
<th>Change in user learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process and product redesign</td>
<td>None to minor</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Functional innovation</td>
<td>Significant</td>
<td>None to minor</td>
<td>Minor</td>
</tr>
<tr>
<td>Institutional innovation</td>
<td>None to minor</td>
<td>Significant</td>
<td>Significant</td>
</tr>
<tr>
<td>System innovation</td>
<td>Significant</td>
<td>Significant</td>
<td>Significant</td>
</tr>
</tbody>
</table>

2.9 Development processes for rethink projects

The transition from being a product manufacturer to being a service provider constitutes a major managerial challenge (Olivia and Kallenberg, 1999; Galbraith, 2002; Brady et al., 2004). Thus ecodesign researchers need to explore the work done by service development and company-oriented researchers (such as the research done with regard to integrated solutions). This research shows that offering services requires company principles, structures and processes that are new to product manufacturers. The main factors identified in the literature are described below.

2.9.1 Customer relations

An important factor when moving into developing integrated solutions is that the company must become customer-centric (Galbraith, 2002; Windahl et al., 2004; Brady et al., 2004). To move to integrated solutions for industries implies a new approach to creating value for suppliers and their customers (Brady et al., 2004). The firms really have to understand how value is created through the eyes of the customer (ibid). To achieve that customer interaction is crucial (Windahl et al., 2004).
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The relationship with the customer changes and a mutual beneficial relationship created. Trust is an important factor for a satisfying relationship with customers when delivering integrated solutions (Brady et al., 2004). The supplier adopts the role of a ‘trusted adviser’ rather than being just a supplier (Shepherd & Ahmed, 2000).

2.9.2 Culture

The culture in service companies seems to be an important factor in service development and realization (see, for example, Edvardsson, Gustavsson, Johnson and Sandén, 2000), but is not nearly as prominent in the literature discussing the development of products.

2.9.3 New skills

Both environmental and non-environmental literature on integrated solutions stress that firms need to develop new skills. Whereas their focus has previously been largely on technical skills, they need to move towards a more balanced profile of skills and expertise, in which customer and market skills are of greater importance than before (Shepherd and Ahmed, 2000). The balanced competence profile suggests that an integrated solutions provider needs to match technical and product competencies with consulting and partnering competencies with a strong focus on customer interaction (Windahl et al., 2004). The key skills and expertise identified fell in the following areas: technology, integration, marketing-business, and customer partnering (Shepherd and Ahmed, 2000).

The sales force plays an important role in selling the new services. Thus the commission systems need to stimulate sales people to sell services or integrated solutions (Mont, 2001; Hockerts, 1998). Reward systems should encourage the selling of solutions (Shepherd and Ahmed, 2000).

2.9.4 Interaction and communication

Secure and effective communication within the company needs to be promoted (Shepherd and Ahmed, 2000). That can be accomplished by setting up linkages and communication channels between departments (Windahl et al., 2004). Processes such as product and service development that were previously separate need to become coordinated in order to develop and deliver integrated solutions.

2.9.5 New innovation potential

FS and integrated solutions are similar in that they both involve institutional innovations or architectural innovations. In other words, the product and the service elements in integrated solutions are not radically changed; instead new combinations of products and services are offered (Windahl et al., 2004). However, there is a significantly effect on the infrastructure and on user learning (Erhenfelt and Brezet, 2001).

Offering integrated solutions gives suppliers an added incentive to design systems that are reliable and easy to maintain from the start (Davies, 2003). Being involved in
providing services allows firms to recognise service problems and thus opportunities to improve system performance. The lessons learnt can be communicated to those responsible for designing and building current and future systems. The increased innovation that will flow from this will result in the design of more efficient systems.

Achieving these benefits requires the creation of interaction and feedback loops between the developers involved. In this respect, it is interesting to note that Kim and Mauborgne (1997) conclude that companies that have been successful at repeating value innovation are those that have taken advantage of the innovation potential in regard to the product, the service and the delivery. In delivery, they include logistics and the channels used to deliver the product to the customer. All three sources need to be considered when seeking new value for customers. Kim and Mauborgne (1997) conclude that value innovators think in terms of the total solution needed by the customer.

The sustainable system triangle, presented in Figure 2.11, fits in well with these findings (Brezet, Diehl and Silvester, 2001). The triangle emphasises the need to find sustainable ways to deliver satisfaction to the consumer using services or artefacts. The development team should consider the innovation potential of the artefact in the physical and institutional context or infrastructure, as well as the potential for new user practices and user learning. In this way, different aspects of the total product system can be considered in the development phase and not just the artefact itself.

Figure 2.11 The sustainable system triangle (after Brezet et al., 2001).

2.9.6 Integrated solutions process

The traditional product development processes in manufacturing companies are based on models developed for physical products. Instead, they need to adopt a solution-focused business model and a solutions development process (Galbraith, 2002; Shepherd and Ahmed, 2000), which must also include environmental management (Hockerts, 1998).

When designing a PSS, for example, the focus is on designing the whole product service system, including such things as the infrastructure (Mont, 2002). Designing a PSS requires the integration of all the parties across the whole life cycle of a product. Integration between service and remanufacturing organisations is especially important to creating economic incentives from service activities that will drive manufacturing or design changes.
Brännström (2001) proposed the development model seen in Figure 2.12. This model, which evolved from traditional product development models, covers the whole life cycle of the product and enables the provider to understand and create value for the customer. This model presents the product support organisation proposed, along with the proposed hardware, software and service processes. Business development has also been added to the model. The company supports product maintenance and upgrading of products securing the functionality of the solutions provided. Having a properly organised company to support the execution of the solutions is essential (Shepherd and Ahmed, 2000).

Brady et al. (2004) promote a customer-focused company, as illustrated in Figure 2.13. The customer-facing unit, the front end, is responsible for developing integrated solutions to a particular customer’s needs and for integrating various product and service components to reach a solution. This unit assumes responsibility for profit and loss and acts as a market channel for products and services developed internally or sourced from external suppliers. The strategic centre’s role is to shift the company towards integrated solutions. It provides the overall strategic direction. As part of doing this, it executes strategy and overcomes hurdles to company change. It also offers central functions such as account planning and performance management, and plays a crucial role in handling the linkages between the firm’s internal and external suppliers of products and service components. The product units and service units, the back end, are responsible for developing solution-ready products and services. Services, for example, may offer systems integration, operational financing and business consulting. This model clearly demonstrates that the interactions between functions in the firm are central to developing and delivering integrated solutions. However, one criticism of this model is that the arrow between the customer-facing unit and the customer should point both ways, for customer feedback and integration are necessary when developing solutions.
2.9.7 Adding environmental considerations

By providing services companies can make more efficient use of materials and products (Heiskanen and Jalas, 2000). The increased incentives to economise in materials use mean that revenues are no longer linked to material flows. The drive to save resources may eventually yield the principal source of revenue.

When developing new business concepts, the new concept needs to be inspired by strong corporate commitment to environmental concerns, sustainability and customer satisfaction (Hockerts, 1998; Mont, 2004).

Most environmental evaluation methods and design tools were developed with physical products in mind. Goedkoop et al. (1999) stress that it is important that companies answer the question; What are the environmental characteristics at the function fulfilment level, and how do these relate to overall environmental loading in society? Hockerts (1998) proposes that an assigned, eco-integrated innovation team be involved in the process of developing new solutions. An eco-efficiency test should be performed to assess the environmental potential of any solution.

Mont (2004) proposes strategies that companies can use to reduce environmental impact in relation to PSS or integrated solutions:

- Improving design and dematerialization by encouraging reuse, remanufacturing and recycling.
- Reducing the total number of produced goods or the impacts per product in each stage of the life cycle.
- Improving the efficiency of use and reducing the number of service units delivered.
- Organising services close to where customers use products so as to reduce the environmental impact associated with transportation.
Theoretical framework

- Considering the environmental impact of additional services.
- Encouraging infrastructure that is less environmentally burdensome.
- Supporting more efficient and effective use and disposal of products.

It should be recognised that including environmental considerations in a business model is not easy. Söderström (2003) studied a firm where a new business concept including the elements of PSS was developed and promoted. It was found that the closer a project came to realization, the less attention was paid to environmental aspects. Companies that seek to embrace the environmental possibilities of integrated solutions face a major challenge.
Research approach
3 Research approach

This thesis reports on the findings from five different research studies, all of which adopted a qualitative approach in which the emphasis falls on exploring and creating understanding and meaning. The studies focused on three areas of ecodesign: A) rethinking approaches for manufacturing companies, B) setting environmental project targets and project selection and C) redesign of products. These are seen as pieces in a puzzle that, when brought together, contribute to a broader picture and a deeper understanding of ecodesign.

The relationship between the different studies is presented in Figure 3.1 and the themes, studies and papers included in the thesis are presented in Table 3.1.

The objective was that the research findings would be useful to both researchers and practitioners in companies.
THEME A
The original research approach was to study how environmental aspects were included, both at strategic and operational levels, when developing rethink strategies.

Functional sales studied as an example of a rethink strategy.

THEME B
Research topics on how firms considered environmental issues in early stages raised.

The project selection process and the target setting process studied.

THEME C
Completion of studying how environmental aspects can be handled at early stages for a redesign Project. Complementing the rethink study and studying an innovative product development process

A redesign project studied. Complementing research themes A and B

Figure 3.1 Illustration showing how the themes of the studies are related.
Research approach

Theme A. Rethinking approaches for manufacturing companies
  o Addresses RQ 1 and 2
  o Functional Sales are studied and evaluated as an example of a rethink strategy.

Functional sales (FS)\(^3\) is an example of a rethink approach, which is considered to be one way of achieving large reductions in the environmental impact of industry. However, the expectation that environmental benefits will flow from FS seems to be greater in academia and the Swedish Environmental Protection Agency (EPA) than in industry. One reason for this discrepancy is that industry perceives FS mainly as a business strategy. The different attitudes to FS indicate a need for understanding how work with FS is performed in industry. The development of market offers and the service and product development were studied as well as the environmental benefits from FS.

Theme B. Setting environmental targets and project selection
  o Addresses RQ 3 and 4
  o The project selection process and how environmental targets were set in specifications were studied in two cases.

Project selection and the target-setting process are crucial strategic activities in companies and particularly in the product development process, and thus are crucial for achieving successful ecodesign. One company from the automotive industry and one from the telecom industry were studied.

Theme C. Redesign of products
  o Addresses RQ 1, 2, 3 and 4.
  o The project to develop a dry capacitor at ABB was studied as an example of a redesign project.

The point of departure for this study was to understand how environmental aspects were handled in a redesign project. An environmental representative of ABB put the DryQ project forward as an example of successful ecodesign. Since it was an innovative case, there was interest in exploring the characteristics of the project and understanding the factors that made for success.

\(^3\) Functional sales (FS) has been used by the author when studying how a rethink approach was perceived to be used by several key operators in industry. It refers to offers companies make to their consumers which include both goods and services and attract payment by fulfilling a consumer need.

The term FS can be misleading, but has become fairly widely used, and is therefore used in this thesis. It is a direct translation of the Swedish word *funktionsförsäljning*, which could be translated ‘Sales of functions’ – arguably a better way of capturing the underlying meaning of the whole concept. It refers to what is actually being sold to the consumer rather than implying that the sale is functional. There is no need to specify what a function is here, as it is the consumer who defines the desired function or need that the provider is attempting to fulfill. The payment for FS is directly related to fulfilling customer needs, and these needs can be specified in different ways. Payment is related to something that is measurable, and the price is related to factors such as the number of times something is performed, the length of time a function is provided, or the number of kilometres for which a function is provided. Hence, what the function actually is, is negotiated and agreed on by the parties involved.
### Table 3.1 Themes, studies and papers included in the thesis.

<table>
<thead>
<tr>
<th>Theme/RQ</th>
<th>Focus</th>
<th>Study/ Paper</th>
<th>Paper title</th>
</tr>
</thead>
<tbody>
<tr>
<td>A RQ 1,2</td>
<td>Re-thinking business - Functional Sales</td>
<td>I</td>
<td>The Meaning of Functional Sales</td>
</tr>
<tr>
<td></td>
<td></td>
<td>II</td>
<td>How do Functional Sales affect Product development and Environmental Performance</td>
</tr>
<tr>
<td>B RQ 3,4</td>
<td>Setting environmental targets and project selection</td>
<td>III</td>
<td>Making an Ecodesign choice in Project Portfolio selection</td>
</tr>
<tr>
<td></td>
<td>Setting environmental targets</td>
<td>IV</td>
<td>Setting Environmental Targets in Product Development</td>
</tr>
<tr>
<td>C RQ 1,2,3,4</td>
<td>Re-design</td>
<td>V</td>
<td>Managing Radical Innovation and Environmental Challenges- Development of a dry Capacitor at ABB</td>
</tr>
</tbody>
</table>

### 3.1 Research Design

A qualitative inductive approach was used in all studies. An inductive approach was chosen since relatively little research has been performed in the studied areas and further understanding was needed. The theory building was based on the results from the empirical material and compared to existing theory. In study II, rethinking business, the conceptualisation and theory analysed in study I, the literature search on FS, was used to compare some of the results from the studies.

Studies, II and V in theme A and C are case studies. In a case study, a specific phenomenon such as a program, an event, a person, an institution or a group is studied. It needs to be a clearly defined system, and cases should be carefully selected to fit the research purpose (Merriam, 1994). As a research strategy, case studies focus on understanding the dynamics present in single or multiple cases (Eisenhardt, 1989). This approach was chosen to study the theme in A and C since little is known about rethinking business and redesign from an environmental perspective. The current perspectives seemed inadequate because they lack strong empirical substantiation (Eisenhardt, 1989). A further reason for choosing a case study approach was that FS is interpreted differently in academia and in industry. Thus six cases of FS were selected from the manufacturing industry in order to clarify and understand the FS concept and compare the empirical findings with the theory on FS. In theme C (redesign), a project was studied from start to executed product.

The data collection methods used in case studies include studies of archives, interviews, questionnaires and observations (Eisenhardt, 1989). Interviews were the main data collection method used in the studies reported here, as well as company-specific internal
Research approach

and official documents. More details about the approach to the interviews are given in section 3.2.

In theme B, specific parts of the product development process were studied. Two companies were selected, one a company in the automotive industry while the other was in the telecom industry.

Table 3.2 Studies included, mapped with papers, research design and data collection method.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Focus</th>
<th>Type of industry</th>
<th>Respondents</th>
<th>Research Design</th>
<th>Data collection</th>
<th>Study/Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Functional Sales</td>
<td>Literature study</td>
<td>-</td>
<td>Literature review, conceptual paper</td>
<td>Literature review</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>Re-thinking business - Functional Sales</td>
<td>Manufacturing industry –3 large and 3 small firms</td>
<td>Product developers, business developers, and environmental managers (n=23)</td>
<td>Case study Qualitative deductive approach</td>
<td>Interviews Documents</td>
<td>II</td>
</tr>
<tr>
<td>B</td>
<td>Project selection</td>
<td>Manufacturing 1 large firm</td>
<td>Environmental, market and product development representatives (n=4)</td>
<td>Interview study Qualitative inductive approach</td>
<td>Interviews Documents</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>Target setting and project selection</td>
<td>Manufacturing and telecom 2 large firms</td>
<td>Business developers, environmental managers, product planners and project leaders (n=12, 4 are the same as in study III)</td>
<td>Interview study Qualitative inductive approach</td>
<td>Interviews Documents</td>
<td>IV</td>
</tr>
<tr>
<td>C</td>
<td>Re-design</td>
<td>Manufacturing 1 large firm</td>
<td>Project managers and project members (n=10)</td>
<td>Case study Qualitative inductive approach</td>
<td>Interviews Project documentation</td>
<td>V</td>
</tr>
</tbody>
</table>
3.2 Interviews

In all empirical studies the data was collected using qualitative semi-structured interviews. Such interviews have been used in other studies to obtain descriptions of how the respondents interpret the meaning of specific phenomena (Kvale, 1996). They were thus considered suitable for these studies.

Guidelines for the interviews were developed in order to focus on specific themes in each company. The respondents were allowed to expand on any statement they considered important, so throwing light on their perceptions of the studied phenomena. Qualitative semi-structured interviews were chosen because the respondents’ own views of conditions were being investigated, and thus they needed the freedom to specify what should be taken up at the interview (Westlander, 2000).

The interviewees were usually chosen in cooperation with the companies, and were selected because they were knowledgeable about functions that were important for understanding the research topic. The numbers of interviews conducted was determined by an iterative process, with some analysis being done before performing additional interviews. This approach was adopted in an attempt to reach theoretical saturation for each case. This point is reached when learning about a phenomenon is minimal from new input (Gustavsson, 1998). The goal was to achieve saturation for each case by performing some analysis and then adding new respondents when it became clear that there were questions that needed to be addressed.

According to Eisenhardt (1989), two issues are important in reaching closure: stopping adding cases and stopping the iterating between theory and data. The number of cases for each study was, however, planned in advance, which, as Eisenhardt (1989) points out, is often necessary because of the various constraints in case studies.

The interviews were generally conducted with one respondent at a time, but in some cases two respondents were interviewed together. In study V, theme C, some interviews were done by a colleague. However, the guidelines for those interviews were drawn up collaboratively and both authors analysed all the interviews.

The interviews lasted between 45 minutes and 1½ hours, and were all performed at locations chosen by the respondent. Some interviews were conducted on a one-to-one basis, while at others a co-worker was present. All the interviews were taped and then transcribed. Several interviews were followed up in further telephone contact with the respondents in pursuit of the goal of reaching saturation point. Representatives from the companies that participated in each study have read and validated the results concerning their respective companies.

The transcribed interviews were structured by organising the text into different categories. The interviews were coded according to the categories derived from grounded theory (Gustavsson, 1998). These categories arose both from the themes in the interview guidelines and also from findings that became apparent when structuring the interviews. For studies II and V, the authors performed separate coding before an analysis was conducted. For studies III and IV, the coding was done by the author and
validated by a colleague in order to increase the reliability of the analysis of the interviews.

In study II and IV, where more than one case was included in the study, each case was treated as a stand-alone unit in the analysis. Each was analysed separately before cross-references were made. This approach allowed the unique patterns of each case to emerge before patterns across cases were analysed, and gave the researchers rich familiarity with each case (Eisenhardt, 1989).

In the case studies and the interview studies, the main goal was to develop theory from an inductive process. In other words, developing categories for interpreting the information contributed to the development of a theory to describe the meaning of the information (see also Merriam, 1994).

3.3 Quality of research

The quality of research is related to the internal and external validity of the results of the studies. Internal validity relates to the extent to which the results of research correspond with what has been studied and accurately capture the studied processes. External validity relates to the extent to which generalisations can be drawn from the research and to whether the results are useful for situations other than the ones studied.

In relation to interviews, validity reflects the skill with which the interviews were conducted and analysed (Kvale, 1996). It is related to the researchers’ ability to adopt a critical outlook during analysis and to check and test their own findings. It is also related to the researcher’s questioning of the information given by respondents to ensure that it is realistic and true and capable of interpretation.

One way of increasing the validity of interviews is to allow respondents to validate the results (Merriam, 1994). This approach has been used in all the studies reported here, for the respondents in each study read and validated the results. Another way of increasing the validity is to allow a colleague to evaluate and comment on the results during the study (Merriam, 1994). In the studies reported here, a colleague did participate in the analysis of the interviews (see section 3.2).

3.3.1 Generalisations of findings

There has been much debate about whether it is possible to generalise from qualitative studies. This debate has often focused solely on generalisations from single cases or quantitative studies (Eisenhardt, 1989). However, there are a number of different types of generalisations. Kvale (1996) suggests that it is possible to make analytical generalisations from qualitative interviews, meaning that it is possible to assess whether the results from a study can provide guidance for understanding what is likely to happen in another situation. Gustavsson (1998) speaks of theoretical generalisations and argues that the conceptual pattern found from a study is valid for the studied process regardless of whether it exists in other areas or not. Eisenhardt (1989) argues that there are ways of strengthening the possibilities for making generalisations from case studies:
Research approach

- Having thick and rich description of cases so that readers interested in using the results have enough information to evaluate them.
- Providing a description of how typical the case studied is, and describing its characteristics so that a reader can compare the case with their own situation.
- Undertaking cross-analysis within a case or between different cases.

For the studies in this thesis, the goal has been to describe the cases richly enough to enable readers to make their own evaluation of them and compare the characteristics of these cases with their own situation. For study II, a rich description of the cases is presented in Ölundh (2003). Cross-analysis has been done within cases, and for study II and study IV between cases. The results are to be seen as results for the studied cases that readers can learn from and apply to their own situations, while taking contextual differences into account.
4 Summary of appended papers

4.1 Paper I: The Meaning of Functional Sales

Authors: Mattias Lindahl and Gunilla Ölundh.

(The authors shared the responsibility for the analysis and writing of the paper. Lindahl mainly performed the literature search.)


4.1.1 Purpose

The purpose of the paper was to describe and clarify some of the concepts used in articles dealing with environmental concerns and rethinking business concepts. Several terms were used to discuss similar subjects and clarification was needed. Eco-efficiency services (EES), product service systems (PSS) and functional sales were covered.

4.1.2 Research approach

The article is based on a literature review. Relevant references in the reviewed articles were followed up. The basic keywords in the literature search were ‘product service systems’ and ‘functional sales’.

4.1.3 Results and conclusions

The review and discussion of the literature clarified the relationship between different concepts and also defined how functional sales are perceived by the authors. Creating customer value was found to be essential to the concept of functional sales. A focus on the function instead of on the product created a possibility for changing how companies sell and develop their products. The company could retain ownership of products and increase their efforts to fulfil customer needs by offering services. One of the strengths associated with functional sales is that it provides an arena where business and environmental interests can meet.

While functional sales do not always lead to environmental benefits, it was found that in some cases, depending on the solution adopted to fulfil consumer need, they do offer a way to move towards a more sustainable society. It was concluded that design solutions for functional sales should actively consider environmental concerns in order achieve possible environmental benefits.
It was proposed that research should be undertaken into how industries use the concept of functional sales, for example, in product development, in ways that promote sustainable development.

4.2 Paper II: How do functional sales affect product development and environmental performance?

*Authors:* Gunilla Ölundh and Sofia Ritzén

(This paper was based on the results from Gunilla Ölundh’s licentiate thesis (Ölundh, 2003). Ölundh designed the study in cooperation with Ritzén. Ölundh performed the empirical work, and the analysis was done in cooperation with Ritzén. The paper was written by Ölundh, with Ritzén as an adviser.)


4.2.1 Purpose

The purpose of the research was to explore functional sales activities within manufacturing companies and to see how these affected product development. Of particular interest was to explore how environmental aspects were taken into consideration while developing products and services included in FS, and whether or not companies could use functional sales as an instrument for achieving environmental benefits.

4.2.2 Research approach

The main method of data collection was qualitative research interviews with product developers, business developers and environmental managers. Six companies were included in the study. A total of 22 individuals were interviewed using semi-structured interviews. All the interviews were subsequently transcribed, coded and analyzed.

4.2.3 Results and conclusions

An environmental approach to developing FS involves keeping both environmental considerations and value creation in mind. It is important to 1) consider environmental aspects at the level of business strategy and solutions rather than at the level of artefacts, and 2) have strong interaction between the development of services and artefacts in order to offer total solutions.

The results show that the companies investigated extended their sales offers and added services such as financial and maintenance services to pre-existing products, so creating value for their customers.
The conclusion is that even though the driving forces for offering FS are not environmental, FS can be used to some extent as an environmental strategy. However, there is a need to integrate the environmental aspects at the business development stage and so to take a more holistic viewpoint than when the focus is solely on developing artefacts.

The environmental benefits were found to be related to usage-phase management of the products, involving such things as optimising solutions, choosing the best product to use, and making sure that the product was actually used.

When it comes to the design of products, it was concluded that offering FS strengthens the motivation for changing product design. One important factor here is a stronger focus on the life cycle cost (LCC) of the products. Focusing on lowering the LCC was, however, already a strong motivator for product development in a number of the companies studied. The reason for this appeared to be much the same as the forces driving product developers to internalise usage costs. Facilitating product maintenance and refurbishing were also perceived to be valuable outcomes for products used in FS offers. However, the companies often lost control of the products after a few years when the FS contract ended and the products were then sold on in the traditional way. A new situation that was found to be affecting product development was that the products used in FS offers became less price-sensitive.

It was concluded that when developing FS, there must be close interaction between the developments of the artefacts, the services, and all development needs. In order to be successful in creating value for customers, companies need to take advantage of the innovation potential in the product, the service and the delivery. All three components need to be considered when seeking new value for customers. Value innovators think of the total solution needed for the customer. This perspective is often missing in manufacturing companies, where services and delivery systems are added to an already existing product. A well-structured business development process is crucial if there is to be the transparency between company activities that is needed for successfully bringing something like FS to market.

### 4.3 Paper III: Making an ecodesign choice in project portfolio selection

*Authors:* Gunilla Ölundh and Sofia Ritzén

*(Ölundh, with Ritzén as an adviser, performed the empirical work and analysis. The paper was written by Ölundh, with Ritzén as an adviser.)*

4.3.1 Purpose

This paper reports on a study of the project selection process in one manufacturing company. The purpose of the study was to explore how environmental considerations could be included in the early phases of product development before the specifications for a project are set.

4.3.2 Research approach

This paper presents the working process in one manufacturing company. Four semi-structured interviews were performed, in an iterative process, with environmental, marketing and product development representatives. Representatives of the company have confirmed the results described.

4.3.3 Results and conclusions

The paper describes how a company handles project selection and how environmental aspects have been integrated in that process. The study leads to the conclusion that project portfolio management has several benefits and that by including environmental aspects as contributing to technical performance, environmental considerations can be brought to bear in project selection.

In the case described in the paper, environmental performance targets were part of the company’s product identity. These targets were among the evaluation criteria used in screening projects during the selection processes. The environmental performance targets were stated in the directive for a project development project, thus ensuring that they would be included in the final product specification. Including environmental aspects in a structured portfolio selection process ensures that environmental aspects are considered at a strategic level.

Integrating environmental aspects into the product planning process is one way to ensure that environmental aspects are considered at a strategic level pre-specification. Including environmental performance criteria in the strategic business decision process is an important step. It leads to environmental considerations being connected to strategic activities and to environmental considerations being highlighted in decision processes prior to product development. One must, however, remember that the evaluation of ideas and the considerations taken into account in preparing to make a decision are dependent on the business idea, business strategy and product strategy. These strategies must include environmental considerations if the project evaluation and the decision preparations are to become environmentally proactive.
4.4 Paper IV: Setting environmental targets in product development

Authors: Gunilla Ölundh and Sofia Ritzén

(Ölundh, with Ritzén as an advisor, performed the empirical work and analysis. The paper was written by Ölundh, with Ritzén as an adviser.)

Status of paper: Paper has been submitted for publication in a scientific journal.

4.4.1 Purpose

There is a need for increased understanding of how to include ecodesign activities in the early stages of product development. One part of this is to explore the target-setting process in companies and how product development projects and product concepts are selected. These processes are of great importance both in reducing the environmental impact of products and in securing a company’s competitiveness.

The purpose of the study presented in this paper was to explore how environmental aspects were considered in the target-setting process for product development projects, and also to explore how environmental aspects were considered when project concepts were selected.

4.4.2 Research approach

The empirical study was based on semi-structured interviews with different actors in two companies, one of which developed trucks while the other was in the telecom sector. The twelve respondents included business developers, environmental managers, product planners and project leaders. Four of the respondents had also been interviewed for study III. The interviews were performed at a location chosen by the respondents and were recorded and transcribed. Further telephone interviews were conducted with some of the respondents in order to clarify information or to gain new data. These interviews were documented by taking notes.

4.4.3 Results and conclusions

It was found that environmental managers are organised centrally, but special environmental groups and environmental coordinators are decentralised in different departments. This contrasts with the situation in the mid-1990s when centralised environmental departments were more common.

The research revealed how the companies studied organise the setting of environmental targets and the integration of environmental aspects into project selection.

Product planners and managers often use predefined environmental targets in the early stages of product development. An environmental group, which includes people with
environmental expertise, product developers and managers, develops the targets. The advantage of this approach is that environmental aspects are included early, thus facilitating discussion of environmental aspects of the project. The challenge, however, is to really use the targets and to discuss them at a strategic level. If this is not done, the pre-defined targets are simply added to the project specifications and responsibility for environmental aspects is left to engineers in the operational stages. The level at which the environmental targets are set and how challenging they will be needs to be raised early in the discussion of the environmental and technical possibilities for a project. It is important that environmental experts who are well known and enjoy high status within the company are involved in setting environmental targets. This job should not be left only to product developers and product planners.

The inclusion of environmental aspects in project selection is usually linked to strategic fit with the company’s product strategies and business strategies. Environmental product targets that are linked to these strategies are a useful criterion when selecting new product development projects.

**4.5 Paper V: Managing radical innovation and environmental challenges – Development of a dry capacitor at ABB**

*Authors:* Gunilla Ölundh and Johan Tingström

*(The authors have shared the empirical work and analysis. The paper was written in cooperation between the authors, with Ölundh as the main contributor.)*

*Status of paper:* Paper has been submitted for publication in a scientific journal.

**4.5.1 Purpose**

An understanding of how companies that achieve redesign or rethink work is needed in order to understand the mechanisms for achieving large environmental benefits. Companies may, however, produce several products that represent redesign or rethink without improving the environmental performance of the product. Yet the possibility does exist, and it is thus important to understand how companies can act in order to really take advantage of environmental possibilities.

The purpose of the study was to explore the driving forces for taking environmental considerations into account in a redesign project. The purpose has also been to understand how the development process worked and how the environmental considerations were handled during the whole product development process.

**4.5.2 Research approach**

The DryQ project was carried out early in 1998 and the first unit was produced in 2001, but decisions and actions that affected the final result began as early as the 1970s. It was
a high-risk project with a high degree of technological uncertainty. The study is based on in-depth interviews with ten respondents, both managers and project members.

4.5.3 Results and conclusions

Ecodesign often calls on companies to rethink and redesign projects. But in order to understand how ecodesign is to be taken into account when attempting radical product development, ecodesign researchers need to understand, use and benefit from traditional innovation theories as well as from ecodesign theories. When it comes to radical product development, the formalised product development models used for incremental product development are not very suitable. Radical product development requires a different style of management, one that involves experimentation, iteration and strong leadership. It seems that the most important factor in finding innovative environmental solutions is not an environmental checklist but rather a mindset that is focused on really improving the product. The project must allow scope for finding new solutions that go beyond merely satisfying the lowest level on an environmental checklist. While such a checklist may be useful to ensure that some environmental targets are met, it may encourage the project and the engineers to commit to reaching only the minimal level, rather than pursuing radical solutions. The possibilities of improving the environmental performance along with the technology need to be embraced.

It is important to build commitment to environmental issues, which results in motivation to solve them. From the outset, the management must make it clear to the project team that they have a great opportunity to radically improve both the product and its environmental performance. Involving the project organisation in setting challenging environmental targets early on is a valuable exercise. It is also important to reward environmental improvements, and to use some tools to measure the environmental improvement in some way. These tools should be capable of being used during the development process to assist in deciding between different possible solutions.
4.6 Overview of appended papers

Each of the studies included had its own specific research focus and empirical context, but together they all contributed to an understanding of the purpose of the research. In this section, each study is summarised in order to give an overview of interesting findings. A more detailed discussion follows in the next chapter.

Table 4.1 Overview of appended papers.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Subject of paper</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Theory of functional sales</td>
<td>Functional sales provides an arena where business and environmental interests meet.</td>
</tr>
<tr>
<td>II</td>
<td>Empirical study of functional sales and rethink</td>
<td>Selling services connected to products is an extra marketing strategy. Environmental aspects are often neglected and the design of the product used is seldom affected. Yet possibilities exist for improving environmental performance. Close cooperation is needed between business development, service development and product development.</td>
</tr>
<tr>
<td>III</td>
<td>Empirical study of environmental aspects of project selection</td>
<td>Environmental aspects can be taken into account early on and give rise to discussions at a strategic level in the product development process. The environmental aspects need to be very clear and need to be able to relate to business opportunities.</td>
</tr>
<tr>
<td>IV</td>
<td>Empirical study of the setting of environmental product targets</td>
<td>Environmental targets are often centrally developed and are to be used by product managers and product planners when setting product specifications. These pre-defined targets may lead to discussion at a strategic level but may also simply be added to the specifications without any discussion of environmental possibilities.</td>
</tr>
<tr>
<td>V</td>
<td>Study of a redesign project</td>
<td>Commitment to and motivation for environmental issues need to be cultivated. Management must point out from the start that this project offers a great opportunity to radically improve both the product and its environmental performance. Setting challenging environmental targets early on, involving the project organisation is valuable. The development process must also be adapted.</td>
</tr>
</tbody>
</table>
5 Discussion on ecodesign for redesign and rethink projects

This section of the thesis deals with the first and second research questions (RQ 1 and RQ 2). It begins with description and discussion of the ecodesign experiences in study II and V and then goes on to identify factors influencing how ecodesign is performed in manufacturing companies in the context of redesign and rethink projects.

5.1 Ecodesign experiences from redesign and rethink projects

From theme C, study V, and theme A, study II, it can be concluded that in redesign projects there is a need to acknowledge the environmental possibilities early on, at the concept development stage, in order to really embrace the environmental possibilities from the start at a business level. It should be noted that the project studied in study V was selected due to the environmental improvements that were achieved in the project.

5.1.1 Experiences from redesign, Study V

One interesting statement in the project in study V was made early on at a business level: ‘Developing a new technology offers a very good opportunity for handling environmental aspects. This will be considered for the project.’ The statement shows understanding of the importance of considering environmental aspects early in a project aimed at developing new technology. The environmental direction in the project was strong in that internal and external forces drove the environmental work and the environmental ambition of the project was clearly stated.

Management demonstrated strong commitment to an environmental focus and the project owner had the informal role of an environmental champion. Such a sense of commitment supports quick and adequate decision-making (Meyer, 1997, in Sundström, 2005). This is important, for the success of projects depends on the ability to make quick and relevant decisions (Sundström, 2005). The commitment in the development team was also strong, partly because the project team formulated the environmental targets. The commitment to environmental work was enhanced by the fact that several of the respondents had a positive attitude towards environmental work and expressed their personal satisfaction at working on a project that required them to take environmental considerations into account. The respondents in the development team also stated that environmentally beneficial solutions were highly regarded and received positive feedback from management.
Discussion on ecodesign for redesign and rethink projects

A further positive element was that the team had access to tools that could be used to measure environmental improvement in some way. Life Cycle Analysis (LCA) was used to reduce the complexity of environmental aspects and LCA was actively used in the project to support design decisions. EcoLabs LCA tool was used in order to obtain high-quality data. The new product was compared to the old one in respect of the environmental load it imposed.

Study V showed the value of having an environmental champion, a view that is also supported by other academics, such as Ritzén (2000). In the case studied here, the environmental champion was in a leading position and had an important role in both the technology development and the high environmental commitment. According to respondents, the need for an environmental champion is reduced when the formal procedure to be followed includes environmental aspects. These aspects are then incorporated in the prescribed development process.

Even though the project was not fully formalised as following a structured development process, there were environmental checkpoints in the development process. However, these checkpoints were more in the nature of reminders not to forget environmental considerations than drivers to finding new solutions. Setting challenging environmental targets is more important when a company aims to achieve technical innovations while taking environmental considerations into account.

5.1.2 Experiences from rethink, Study II

In environmental literature, rethink strategies such as PSS, eco-efficient producer services and FS are promoted as environmental strategies. Similar strategies such as integrated solutions are promoted in organisational, service and business literature. The environmental researchers, however, identify and promote the environmental connections that are seldom mentioned in the theory of integrated solutions. For most of the companies in study II, business reasons drove the decision to rethink business. These reasons included a desire to meet customer requirements, create closer and more long-lasting relationships with customers, and get new technology out into the market. The business solutions constituted an opportunity to extend business activities and increase market share by differentiating products by adding services. It is thus possible that businesses lack awareness of the environmental potential stressed in environmental literature or lack incentives to explore environmental possibilities. What is obvious from study II is that respondents seldom saw a connection between developing new business strategies or developing new total offers and achieving environmental benefits.

Such environmental work as was done when developing integrated solutions was mostly connected to the products, reflecting the traditional approach to ecodesign and using material checklists, guidelines and tools such as LCA. As shown in studies I and II, however, service development and business development also need to have an ecodesign perspective if the integrated solutions that are developed are really to yield environmental benefits (see also, for example Mont, 2004). Integrated solutions involve both products and services, and thus the potential for environmental benefits involves how services and solutions are developed as well as the products included in solutions. Environmental considerations therefore need to be taken into account in the total solution and in its parts, such as the physical product and services. Ecodesign needs to
move into new areas in the company and not be restricted to traditional product development.

For a number of respondents, relating environmental benefits to offering FS or integrated solutions represented a new way of thinking. Awareness of linking environmental considerations to offering FS also varied amongst the respondents. When asked to elaborate on the environmental possibilities, a number of the respondents spoke about actions leading to positive environmental effects from offering FS, but there were also other respondents who did not perceive any such benefit. Services such as leasing and other financing services were seen by some respondents as ‘paper products’ that had no effect on the environmental impact of their company’s products.

Those respondents who recognised that environmental benefits could be linked to FS and integrated solutions thought that the environmental benefits were mainly associated with the usage phase of the products by optimising the operation of products (see also White et al., 1999; Mont, 2004) and also by optimising the customer solution, see Table 5.1. Optimising an engineering or business solution was seen as environmentally beneficial, mostly because energy consumption could be controlled.

Choosing the optimal product for different situations for the customers was also seen as environmentally beneficial, as over-sizing could be avoided. Respondents also saw benefits in the use of the product, when, for example several customers could use the same product according to their needs, which would result in the generation of fewer products.

Internalising service and usage costs was seen as strengthening the motivation for lowering the life cycle cost (LCC) of the products. According to the respondents, another benefit in this context was that the provider performed the maintenance of the products, and consequently the products were maintained in good condition.

Because new technology is often more expensive than older technology, getting new technology that leads to reduced environmental impact out into the market is seen as one action that leads to environmental benefits.
### Table 5.1 Actions that lead to environmental benefits, and how these benefits are achieved through offering FS.

<table>
<thead>
<tr>
<th>Actions that lead to environmental benefits through offering FS</th>
<th>How environmental benefits are achieved by offering FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internalising maintenance and service.</td>
<td>Affects product development, leading to good ‘housekeeping’ of products.</td>
</tr>
<tr>
<td>Internalising costs for use.</td>
<td>Affects product development by lowering the usage costs and thereby lowering energy consumption.</td>
</tr>
<tr>
<td>Choosing the product to use.</td>
<td>Able to choose the most suitable product for different situations.</td>
</tr>
<tr>
<td>Using the product.</td>
<td>Enables the product to be used by several consumers instead of just one.</td>
</tr>
<tr>
<td>Optimising an engineering solution.</td>
<td>Optimises the customer’s engineering solution and lowers environmental impact, mainly energy consumption.</td>
</tr>
<tr>
<td>Optimising a business solution.</td>
<td>Optimises the customer’s business operations and lowers environmental impact, mainly energy consumption.</td>
</tr>
<tr>
<td>Getting new technology out to the market.</td>
<td>Able to get new technology – with higher investment cost, lower life cycle cost, and less environmental impact – out to customers.</td>
</tr>
</tbody>
</table>

### 5.2 Factors that influence how to perform ecodesign

This section discusses factors that influence how ecodesign is done in redesign and rethink projects identified in studies II and V. They are environmental ambition, the solution elements, organisational units, innovation potential, process characteristics and skills. In Table 5.2 a summary of the factors are made.

#### 5.2.1 Environmental ambition

*Environmental ambition* is important from two aspects. One is that it reflects the business strategy and the environmental strategy. The second is that the potential environmental benefits identified in the literature are different for redesign and rethink projects (Charter and Chick, 1997). Within companies, however, environmental ambitions are not always set as high as possible, but rather at the level of meeting legal requirements. This was often the case in study II, where the environmental possibilities of a rethink strategy were not fully understood or embraced. In study V, the environmental potential in the redesign project was acknowledged from the start of the project and strongly influenced the direction of the solution.
As mentioned earlier in the theoretical framework, the possible environmental benefits are different for different approaches (see Charter and Chick, 1997):

- Refine – solving emergency problems in products.
- Repair – improving the eco-efficiency of products.
- Redesign – developing totally new products with scope for more innovative solutions taking into account environmental concerns over the total life cycle of the product.
- Rethink – could have dematerialization as an environmental aim for total solutions.

5.2.2 The solution elements

The solution elements are crucial for understanding what elements ecodesign should address. The solution elements included when developing rethink projects differ from those in projects aiming at repair, refine or redesign, where the main solution element is the product. In the redesign study, study V, it was for example the product itself that were in focus in the development process. Rethink projects on the other hand involve a combination of product and services. Ecodesign is needed to be done for adequate solution elements and integrated solutions.

Study II revealed that financial services and maintenance services were common elements in integrated solutions. The actual financial services themselves did not produce ecological benefits, but rather their side-effects of providing incentives for design and behavioural changes. Other solutions involved the supplier acting as a consultant developing solutions for the customer and also taking over operating activities for the customers. In the latter case, the supplier provides both the equipment and the labour to operate equipment. While the integrated solutions offered are different for each supplier, it is evident that both services and products are elements in the integrated offers.

Mont (2004) summarises the solution elements for PSS, and this list can also apply to many rethink projects:

- products, services or combinations of them,
- services offered at the point of sale including financial services and customer training in product use,
- product use concepts such as use or result-orientation,
- maintenance services for extending product life, and
- revalorization services for closing material loops by taking back products, reusing and recycling materials.

5.2.3 Organisational units and skills

The organisational units involved in the ecodesign work are important. Ecodesign need to be performed vertically in the company, meaning that strategic decision guides the ecodesign work. This is also stressed in ecodesign literature (Ritzén, 2000; Simon et al., 2000; Stevels, 2001). An example from study V is that upper management had clearly expressed that environmental performance were of company strategic importance and
the project management expressed that environmental issues were crucial in the project. The environmental direction was guiding the operational work in the project. In study II it was clear that for companies having a clear environmental strategic direction the operational ecodesign work were more widespread.

In study II it was clear that the ecodesign work were performed mostly for products and the ecodesign routines affected the product development work and not the development of services, or the development of integrated solutions. Since different integrated solutions give incentives for different environmental improvements that is also a factor to consider as well as how services are performed (see for example Hockerts, 1998; Zaring, 2001; Hekkert, M.P., van der Pas, F., and Treffers, D.J., 2001; Mont, 2004). The environmental effects of offering integrated solutions were often poorly known in the companies in study II.

In ecodesign literature the importance of regarding the environmental impact over the products life cycle is often put forward (see for example Brezet and van Hemel, 1997; Mont, 2004). This means that knowledge from different organisational units along the products life cycle needs to be regarded when developing products, services and integrated solutions. Study II for example revealed that knowledge of maintenance staff were crucial for developing products that are easy to maintenance. In order to benefit from possible economic and environmental benefits from integrated solutions the product developers need to be aware of how the products are used and what the economic incentives are for different solutions. In study II the products sold in FS contracts became less price sensitive and the LCC of products became more important than investment price or the development cost for a product. This gives incentives for developing products having a low LCC cost. Features for services, in study II, such as IT needed in products for information of product status for maintenance staff or information for user of products needs to be regarded in the development stage.

Several respondents in study II also expressed that product developers need to have a greater understanding for how customers use and benefit from products used in integrated solutions. The value for customers becomes dependent on performance of products and not the product itself. Meijkamp (2000) as well as Zaring (2001) have pointed out that customer behaviour is an important factor to investigate when studying the environmental effects of services. Changed customer behaviour could lead to increase as well as to reduced environmental impact. This means that the feedback into the development organisations from organisational units having customer contact need to be strong.

There needs to be an interaction both vertically and horizontally in the organisation for successful ecodesign.

**5.2.4 Innovation ambition and potential**

Ecodesign literature stresses that ecodesign needs to move from being corrective to supporting innovative solutions (Sherwin and Bhamra, 1999).

In repair and refine projects, the innovation level is usually low and considers only the product. By contrast, redesign projects are more innovative and demand radically new
solutions for products. Rethink approaches can support radically new products and also new business systems. Among the new business systems are integrated solutions, which may require new services in a firm. Study II suggests that it is often only the combination of services and products in integrated solutions that is new, meaning that the elements already existed in the company but are now combined in new ways, in what could be called architectural innovation. This approach is also recognised by Windahl et al. (2003) and Ehrenfeldt and Brezet (2000). The extent of change involved in offering integrated solutions is, however, dependent on what products and services a company has already developed. The step may be a large one for some companies that need to develop both service elements and product elements. This was the case in some of the companies examined in study II.

One differences between redesign and rethink approaches is that the innovation potential increases in rethink approaches, for it is not just the product that is in focus but all the elements constituting the integrated solution. Kim and Mauborgne (1997) and Ehrenfeldt and Brezet (2000) point out that the innovation possibilities in integrated solutions include the user aspects, the service, the physical product used and infrastructural arrangements.

5.2.5 Process characteristics

Process characteristics influence how different projects are managed. It is important to recognise the innovation potential of different projects from an ecodesign perspective since different projects need to be managed differently. Differences in the solution elements and the innovation ambition influence how the development process for different approaches is characterised and managed.

Redesign projects are innovative and iterative, and formalised development processes may be unsuitable because they control the process too much (Verzyer, 1998; McDermott, 1999; Eisenhardt and Tabrizi, 1995). Formalised development processes are more suitable for incremental development projects, such as for repair and refine.

For rethink projects, services and products need to be moulded into an integrated solution. An integrated solution development process needs to be added into manufacturing companies to complement the product development process.

Interaction and communication between service units, product units, strategic units and customer-facing units are crucial (Brady et al., 2004). This requirement also influences how the ecodesign work should be managed.

Process characteristics for redesign projects

The redesign project in study V did not follow any formal project design process. A stage-gate model in line with Cooper (1988) as launched after the project had started. The literature on radical product development makes it clear that radical product development projects are characterised by a high degree of uncertainty and require an exploratory and iterative work process (Verzyer, 1998). This was also the case in study V. New collaborations were also developed in order to increase the technical knowledge and achieve a high level of innovation. Given that formalised stage-gate processes may
be unsuitable for this type of projects, the fact that a formal stage-gate process was not fully introduced may have been positive for the outcome.

A strong leader is essential when project work is not fully formalised (Eisenhardt and Tabrizi, 1995). Such a leader was present for the project in study V.

The project leader was also seen as a strong environmental champion. He had an important role in both the technology development and the high environmental commitment. According to respondents, there is less of a need for an environmental champion when following a formal procedure that includes environmental checkpoints.

A critical factor in solving the technical problems in study V was the new collaboration that was initiated, including five ABB companies in four countries. This enabled knowledge and expertise from several technical areas to be used and combined in a new way.

**Process characteristics for rethink projects**

For the large companies in study II, the services in integrated offers to consumers were often developed by different sales companies or by a central service development department. The usual pattern was for the solutions to first be offered by local sales companies and then become centralised. The services, such as maintenance services, financial services, consultancy services and operating services, were added to existing products to create added value.

There was usually little interaction and collaboration between product and service developers in the company, leading several respondents to complain about the low level of integration for these functions. The literature on the subject stresses that good communication and interaction between departments and function is crucial to successful provision of integrated solutions (Shepherd and Ahmed, 2000; Brännström, 2001; Windahl et al., 2004; Brady et al., 2004). That was not fully accomplished in the large firms studied.

The service development process did, however, become more centralised and controlled, with responsibility for it moving from the sales companies to centralised units. Yet the interaction among departments remained low. Brady et al. (2004) propose that there should be a strategic centre to coordinate activities and provide strategic guidance while ensuring that products and services fit together in integrated offers. Their organisational model for integrated solutions is well suited to overcoming the need for increased interaction and cooperation, and would meet the coordination needs identified by the respondents in study II.

In some firms, special daughter companies were started to develop special services such as financial services or IT services. One reason for doing that was to build and gather knowledge on these subjects.
**Discussion on ecodesign for redesign and rethink projects**

Table 5.2 Factors influencing how to perform ecodesign and ecodesign experiences from studies II and V.

<table>
<thead>
<tr>
<th>Factors influencing ecodesign</th>
<th>Repair</th>
<th>Refine</th>
<th>Redesign</th>
<th>Rethink</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental ambition</strong></td>
<td>Solve emergency problems in products</td>
<td>Improve eco-efficiency</td>
<td>Needs to be set at a business level at an early stage in the project.</td>
<td>Dematerialization is the aim, and the focus is on the whole life cycle of the total solution. The ambition needs to be set at a business level at an early stage in both service and product development.</td>
</tr>
<tr>
<td><strong>Solution elements</strong></td>
<td>Product</td>
<td>Product</td>
<td>Product</td>
<td>Products or new business concepts, which are the elements in an integrated solution involving services, products and delivery of services.</td>
</tr>
<tr>
<td><strong>Organisational units</strong></td>
<td>Mostly design engineers</td>
<td>Mostly design engineers</td>
<td>All functions related to the product’s life cycle including business planners, product planners, industrial designers, design engineers.</td>
<td>All functions related to developing services, products and delivery systems during the product’s life cycle, including business planners, service developers, product planners, product developers.</td>
</tr>
<tr>
<td><strong>Innovation ambition and potential</strong></td>
<td>Solve emergency problems</td>
<td>Improving an existing product</td>
<td>Develop radically new products. Focus on total life cycle of product.</td>
<td>Innovation in regard to services, infrastructure, products used and user behaviour.</td>
</tr>
<tr>
<td><strong>Ecodesign experiences from studies II and V</strong></td>
<td>No study performed</td>
<td>No study performed</td>
<td>Focus on product development. Strong commitment to environmental ambition at management and project level. Environmental targets formulated in the project group. Innovative climate, explorative and iterative. New collaborations beneficial for reaching solution. Environmental evaluation tools (LCA) used actively during the development. Positive feedback for environmental improvements. Gates used in the project.</td>
<td>Environmental considerations seldom recognised at a business level when developing FS solutions. Ecodesign only performed for products, and seldom associated with the possible benefits of offering total solutions. The solution was usually not evaluated from an environmental perspective. To develop products for FS solutions is environmentally beneficial. Incentives increase to perform product development for environmentally beneficial solutions. Environmental improvements are not guaranteed.</td>
</tr>
</tbody>
</table>
6 Discussion of the use of ecodesign in early stages of product development

This section of the thesis deals with the third and the fourth research question (RQ 3 and RQ 4). If and how environmental considerations are undertaken when selecting product development projects are discussed. Four approaches for setting environmental targets are identified and described. The advantages and disadvantages of these four approaches are discussed.

Engineers are often given operational responsibility for ensuring that environmental considerations are taken into account. In study IV, middle managers expressed the view that it is largely the responsibility of the engineers to take environmental considerations into account in product development. As one respondent put it, the work routines for taking environmental considerations into account ‘should be in the backbones of design engineers’.

But if environmental improvements are to be achieved, the responsibility for the environmental performance of a product should not fall mainly on the design engineers. Setting environmental targets for development projects is an essential part of setting the level for the environmental performance of a product or service. The projects a company decides to commit to also play an important role, and thus marketers, business planners and product planners also need to be concerned about environmental issues.

POEMS (Product-oriented EMS) stresses that environmental targets have to be based on environmental evaluation if they are to be relevant (Ammenberg and Sundin, 2004a). Other researchers also stress this point. A number of the tools that have been developed for ecodesign are focused on analysing the environmental impacts during a product’s life cycle so that areas for improvement can be prioritised. In the companies studied, the evaluation process was handled in different ways. In study V, the company used LCA in the development process and continually analysed the environmental performance of different solutions. The companies in studies III and IV performed a general environmental analysis and used the results to identify areas for improvement in new products. This is a time-efficient approach. Once the areas for environmental improvements have been identified, it is more important to put effort and resources into working with solutions rather than performing detailed analyses during each product development project.

In order for a company or a project group to set challenging environmental targets for a project, there needs to be a strong driving force. In studies II, III, IV and V, the following reasons were given for setting environmental targets:

- Strategic importance and company image
- Customer demand
- Present regulations
• Future regulations
• Economic costs related to environmental pollution
• Economic benefits such as resource savings
• An environmental champion

6.1 Project portfolio selection

One step towards achieving high environmental performance is the selection of sound product development projects. Many companies use a method that is influenced by the theories of Cooper (1988). Portfolio management is a dynamic process for evaluating, selecting and prioritising new projects and comparing them with existing ones. Having a structured project portfolio management process ensures that all ideas are evaluated according to the same criteria, such as market attractiveness and technical feasibility. The criteria that are set for a formal project portfolio selection process are important in determining which projects get chosen.

Studies III and IV revealed that the choices made during project selection are based on strategic decisions in the company. For a company with a clear strategy and a way to communicate its environmental ambitions, it was strategically important to include environmental aspects in the evaluation process for ensuring that projects are strategically aligned.

Study IV revealed that for one company the selection criteria simply ensured that the projects selected satisfied environmental regulations. The other company had included their environmental targets in a product’s identity and used these targets as criteria when selecting projects.

Study III shows how a company can integrate environmental aspects in the selection process, see figure. In Figure 6.1 he activities concerning the environmental performance are described. Ideas are evaluated having environmental performance as one criterion. (3). When making decision preparations (4) demands and targets for the environmental performance should be considered and in the final assignment directive for a project demands and targets for environmental performance should be defined (5).

Figure 6.1 The environmental performance included in early stages of product development process when selecting and investigating projects.

In that case, the environmental concerns were related to a strategic decision and a well-defined product identity. The environmental aspects were prioritised and environmental
aspects were a criterion in the standardised evaluation process. This approach ensures that environmental aspects are discussed and considered at a strategic level when selecting projects. However, a problem seen in study III is that managers have difficulty evaluating the economic benefits that will flow from environmental improvements.

Study IV shows that the aspects that companies rate most highly are customer demands and the factors that are crucial for developing a product that will satisfy them. It is important to remember that the evaluation of ideas and the considerations taken into account in decision preparation are dependent on the corporate mission, the business strategy and the product strategy. For companies where the environmental performance of products is less crucial for customers, environmental issues will not be prioritised in project portfolio selection.

6.2 The process of setting environmental targets

The literature on ecodesign stresses the importance of setting product targets that take environmental aspects into account (Cramer, 2000; Simon et al., 2000). Yet there has been little research on how the environmental targets are actually set. Environmental targets should be included in the general target specification. The specification is also as an agreement about what is desired in the end product (Darlington and Cully, 2004).

Environmental targets need to be treated in the same way as the targets for weight, performance and the like (see also Bragd, 2002; Handfield, Melnyk, Calantone, R. and Curkovic, 2001; Magnusson, 2003) and need to be integrated in the technical specification. It is, however, clear that environmental target are different in the sense that they not only define the performance or characteristics of a product but are also related to personal values and ethical decisions. The respondents in studies III, IV and IV stated that they considered environmental work to be closely related to ethical decision-making. This linkage is problematic, for different people have different interests and different personal values and act in accordance with them. Consequently different people in a company will act differently. There is thus a need to have a really clear statement of the strategy behind the objectives relating to environmental issues in product development. The business aspects of working with environmental issues need to be worked through and targets set accordingly (see, for example, the strategies suggested by Reinhardt, 1999). This strategy also needs to be communicated very well throughout the company.

It is clear that in the balancing process, when different demands to be included in a specification are being considered, there is need for someone to ‘fight’ for the inclusion of environmental issues (see also Bragd, 2002). This has to be someone with interest in and knowledge of environmental issues.
The empirical studies (studies III, IV and V) presented in this thesis enabled four ways of setting environmental targets for projects to be identified:

- Breaking down environmental targets for each project separately from a product identity
- Setting targets for prioritised business areas at a business level for each project separately
- Developing the level of the environmental targets in the project development team
- Developing ecodesign specifications to be used in all project

6.2.1 Breaking down environmental targets for each project separately from a product identity

In the automotive industry, for example, it is quite common to develop a product identity for the end products. This identity prioritises certain properties of the product that are described in terms of how the company intends customers to perceive it.

In study III and IV, one company had a well-developed product identity and environmental properties were one of seven prioritised properties for their product. The ambition level of the environmental targets was first suggested by the person responsible for that property and was then discussed and decided on by the R&D management team. The environmental performance targets were developed from environmental evaluations of the products, regulations, the environmental policy of the company and customer demands. Ecodesign guidelines were developed for the use of design engineers during the product development process.

Working through and describing the environmental properties at a product level has a positive effect. The respondents stated that having environmental performance as one of the prioritised product properties resulted in environmental issues being discussed and considered more at a management level when developing specifications for a project. It also gave managers a document to rely on.

However, study IV revealed that respondents find it difficult to break down the environmental property targets for each project. Each product development project is focused on one part of the end product, such as the engine. In order to be able to break down the targets, it is necessary to understand how specific elements of the end product contribute to the total environmental performance. For example, it is important to consider the weight of each part developed and whether the part needs to be recyclable in order to fulfil the target for the end product. This is a general difficulty when setting targets. The most significant problem related to the interpretation of requirements is that they are not clear enough. The solution is to provide adequate information, clarifying the context and the underlying intent of each requirement (Almefelt et al., 2003).

Respondents found it hard to argue for environmental performance targets in a situation when conflicting targets were being discussed. One reason for their reticence was that they found it hard to attach a monetary value to environmental benefits. Consequently other targets that were easier to assign a monetary value or that would clearly create
value for customers tended to be prioritised. One respondent even claimed that more environmentally beneficial solutions were sometimes rejected because of difficulties in finding measurable and monetary arguments to support them.

Another difficulty was that different aspects of the product identity had different status and the environmental properties were not the ones with highest status. This also resulted in it being easier to prioritise other conflicting properties.

The properties also varied in how well they were defined. Environmental properties were regarded as less well defined than other properties, leading to difficulties in understanding them and breaking them down for separate projects.

It also became clear that the status of the person responsible for a particular property and how well he or she was known in the company affected the willingness to contact that person for information or for discussions and meetings.

These results are similar to those found by Bragd (2002), who identified the following factors affecting how the description of a property is interpreted: 1) different ambition levels for different properties, 2) some properties have a stronger profile in the company, 3) the reputation, knowledge and bargaining power of the person in charge of a property is important and 4) different departments have different foci and are interested in different aspects of the project.

### 6.2.2 Setting targets for prioritised areas at a business level for each project separately

When an aspect is especially important from a business perspective, it is developed for each project at a business level. This was the case with properties influencing the energy consumption of products for an organisation in study IV. These issues are often central to the performance of a product, the use costs for consumers and its environmental performance. The targets are developed taking economic and environmental considerations into account.

In the above case, it is interesting to note that an environmental expert in the company stated that lowering the energy consumption of products was an objective in the companies EMS. The energy consumption of products is an important environmental issue. The environmental ambition described in the EMS is discussed for each product. This procedure for setting environmental targets is only followed for strategically important aspects and the company also needs to complement this procedure by including more environmental considerations.

### 6.2.3 Developing the targets in the project development team

In the redesign project studied in study V, great commitment was achieved by having the development team set the challenging environmental targets. Environmental literature also affirms the importance of creating commitment and ownership of targets if they are to be fulfilled (Almefelt et al., 2003).
Even though the targets for the project were formulated by the project team, support for having challenging targets was expressed at a business level. From the very start of the project, the environmental demands were in focus and the environmental targets were set very early on. Both consumer demands and the business strategy of the company supported and demanded challenging environmental targets.

Several of the project members stated that they perceived the targets formulated by upper management as being of the nature of ‘develop a product with less environmental impact than the preceding product’. The objective of the company was to ‘improve the environmental performance of a product’. This objective does not include any measurable or specific targets, but simply urges that the product should be improved. Some targets were, however, absolute, such as the requirement to have a recyclable product and to reduce the use of lead and oil. The perception was that there was a strong environmental vision in the project group. Such a vision is very important, especially in uncertain projects (Verzyer, 1998).

6.2.4 Developing ecodesign specifications to be used in all projects

Ecodesign specifications to be used in the design of a product, largely by design engineers, can be viewed as environmental targets in product development. They can also be considered as guidelines in product development projects, though more specific guidelines exist in other companies. For one company in study IV, ecodesign specifications were the main means of communicating the environmental considerations to be taken into account. The specification was divided into obligated (legal) requirements and optional requirements.

Environmental experts and product developers developed the specifications, which were then approved by an upper management team in a corporate review process. This approach meant that a small group of people in the company developed the targets for all projects. The specification then needed to be communicated and used by both managers and designers. The communication and decision process for general ecodesign specifications is illustrated in Figure 6.2. The illustration makes it clear that ecodesign specifications are meant to be used in the whole development process and when setting targets for the projects. The ecodesign specification passes through several levels of management before ending up in a project. The respondents complained that some environmental aspects that were not yet addressed in the specification were ‘spinning around’ in the organisation and were hard for managers to grasp.
It is clear that the ecodesign specifications should be added to the project and product specifications. The project managers and product managers were supposed to clarify which of the targets were applicable to each project. According to respondents, the ecodesign specifications were routinely added to the specifications, but they were not fully prioritised and discussed at an upper management level. This approach increased the risk that these specifications would be seen as optional requirements that could easily be disregarded. The problem may be that environmental specifications are not really interesting to managers, which contributes to the failure of design engineers to prioritise them. The responsibility for seeing that environmental specifications are fulfilled falls on the designers. One manager explicitly stated that this was their role. Several respondents also made the point that it would make a difference if the upper management declared that environmental issues were to be treated as more strategically important than they had been. It is clear that the ambition level to fulfil the legal demands made on products was aligned with respondents’ perception of the business strategy. This way of setting environmental targets seem to be suitable when wanting to secure an environmental performance level in projects. Relating this to the different project approaches discussed earlier, this way is most suitable for repair and refine projects in which the environmental ambition is mainly to satisfy legal requirements.

6.2.5 Advantages and disadvantages

The ambition level of environmental targets should be in line with the business and environmental strategy of a company. The method of setting environmental targets needs to be adjusted to the working procedures. Each of the identified methods has its own advantages and disadvantages (see Table 6.1).

The statement that it is important to get managers interested in environmental issues may seem trite, but it is a reminder that it is still difficult for managers to accommodate environmental aspects among all the other aspects they need to consider. Yet commitment is crucial for achieving environmental targets. That is why pre-defined targets may result in less commitment when they are handed to a project group then when they are developed by the project group.

The ideas of Product-oriented EMS (POEMS), with product-specific reviews and defining procedures and responsibilities, need to be complemented with an approach that creates commitment and ownership of the environmental targets within the product development project.
Discussion of the use of ecodesign in early stages of product development

When using general ecodesign specifications, there is a risk that environmental targets are just added to the project by tacking them on to the pre-defined list. Yet there mere presence on the list creates an opportunity for managers to think about environmental aspects and take a stand on which of the pre-defined targets (including ecodesign) are applicable to a specific project. An argument can then be made for including environmental improvements at an early stage. Including general ecodesign specifications on the list is also one way of ensuring that obligatory environmental requirements are met. Both environmental specialists and product developers should develop the targets.

Managers complain that environmental targets are often difficult to quantify and follow up to see whether they have been achieved. The classic advice of having specific targets is still valid, but is apparently not always easy to achieve in practice.

There is also a risk that targets such as those describing a product identity are so general that they are of little use to those who need to refer to them when writing specifications.

When developing environmental targets for products, it is a good idea to maintain a customer focus and concentrate on how consumers perceive the products. This approach creates a business rationale for the environmental targets.

<table>
<thead>
<tr>
<th>Procedures for setting targets</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breaking down environmental targets for each project separately from a product identity</td>
<td>Gives a vision of how consumers are to perceive the product. Customer value is considered and not just environmental considerations. Developed at a business level.</td>
<td>Difficult to apply to subprojects for complicated products.</td>
</tr>
<tr>
<td>Setting targets for prioritised business areas at a business level for each project separately</td>
<td>The environmental targets are set at a strategic level for each project.</td>
<td>The environmental level of targets needs to be regulated in, for example, EMS.</td>
</tr>
<tr>
<td>Developing the level of the environmental targets in the project development team</td>
<td>Creates commitment to the environmental targets in the project team. The environmental possibilities in a project can be discussed and the environmental ambition can differ in different projects.</td>
<td>Risk that no environmental targets are set. Management must communicate the environmental strategy of the company if the targets are to fit that ambition level.</td>
</tr>
<tr>
<td>Developing ecodesign specifications to be used in all project</td>
<td>Ensures a specific environmental ambition level by mandating requirements. Targets can be discussed at a business level.</td>
<td>Easily becomes too routine, without creating awareness of or commitment to the requirements. Optional demands may easily be overlooked and not prioritised.</td>
</tr>
</tbody>
</table>
7 Conclusions: How to modernise ecodesign

This section of the thesis addresses the two research objectives (RO 1 and RO 2) and offers recommendations for modernising ecodesign so that it fits redesign and rethink projects and so that environmental considerations are taken into account in project selection and target setting. The recommendations follow from the preceding discussion of the four research questions. Modernising ecodesign means taking advantage of environmental benefits when developing solutions rather than using ecodesign simply to ensure that legal requirements or customer demands are met. Ecodesign is a strategic issue and should be included in early product development activities. These recommendations for how to modernise ecodesign are mostly suitable for manufacturing companies that want to have high environmental ambitions. These recommendations are also complementary to the research findings on integrating ecodesign into product development that are often focused on bringing about changes in the overall view of issues addressed in ecodesign.

As mentioned earlier, commitment is crucial to making quick, adequate decisions. Strong commitment from management is essential if environmental aspects are to be integrated in products and services (studies II–V). The environmental opportunities should be related to the business strategy of the company. It is also important to reward environmental improvements in the project. Management also needs to have a strategy to increase the commitment of team members to environmental targets.

One way of modernising ecodesign could be to further investigate how EMS and product-oriented EMS can be used for this purpose. Ammenberg and Sundin (2004a, 2004b) promote the use of EMS and POEMS for setting environmental targets for product development. In study IV, environmental targets in the EMS affected how crucial product performance criteria were set. When discussing this possibility, it is important not to standardise the environmental work too much and to avoid the work being of a corrective character.

Recommendations on how to modernise ecodesign can be summarised in six points, which are expanded on the text which follows:

- Perform ecodesign both vertically and horizontally in a company
- Increase interaction
- Take advantage of innovation potential
- Take environmental considerations into account in the project selection process
- Set environmental targets
- Develop ecodesign procedures that fit the characteristics of the development process
Ecodesign should be aligned with the company’s strategic ambition. If companies are to have high environmental ambitions, it is important to identify the internal and external driving forces (legal, business rationale, or other) that will fuel this ambition.

### 7.1 Perform ecodesign both horizontally and vertically

Ecodesign should be performed both vertically and horizontally in a company (see figure 7.2). By ‘horizontally’ it is meant that the entire life cycle of a product should be scrutinised for possible environmental improvements (see, for example, Brezet and van Hemel, 1997). This means that several organisational units along the product’s life cycle need to be involved in the process of improving its environmental performance.

The vertical component reflects the reality that works towards achieving possible environmental benefits starts at the strategic business level. Environmental considerations should thus be taken into account in strategic decisions in product development. The strategic direction guides the environmental ambition in product development projects. When planning products and services, the environmental aspects should be considered. Ecodesign should also be performed when developing integrated solutions in rethink projects and should be integrated into project selection and when setting product targets.

*Figure 7.1 Horizontal ecodesign activities span the product’s life cycle and vertical activities proceed from a strategic level to operational levels.*
7.2 Increase interaction

Ensure effective communication within the company. Both vertical and horizontal interactions are crucial, as illustrated in Figure 7.2. Since a life-cycle perspective is needed in ecodesign, it is beneficial to draw on the knowledge of all actors along the product’s life cycle when engaging in both redesign and rethink projects. Their knowledge can contribute to recognising possible environmental and economic options during product development. For example, in study II the companies found it valuable to draw on the knowledge of maintenance and service staff in order to improve the design of products used in integrated solutions and so facilitate the maintenance and upgrading of products. When developing new total offers, it is also positive for there to be interaction between those engaged in business development, service development and product development. Such interaction was lacking in several firms in study II, as the respondents were well aware. They would have liked to see more interaction in order to formalise and organise the development of the elements required for the integrated solutions. The elements used in integrated solutions need to be compatible, and need to be examined for possible economic and environmental benefits.

The importance of the vertical integration became clear when it came to selecting projects and setting product targets. Direction needs to be given from a strategic level.

7.3 Take advantage of innovation potential

While a checklist giving the minimum requirements for environmental specifications may be useful, it may also block the company from developing radical solutions. It seems that when it comes to developing environmentally innovative products and integrated solutions, the most important thing is not to have environmental checklists but rather to have challenging targets and a mindset of really striving to improve the product. There needs to be room in a project for finding new solutions that exceed the lowest environmental requirements.

Management should point out from the start that the project represents a great opportunity to radically improve both the product and its environmental performance.

It is clear that several of the companies in study II did not take advantage of the innovation possibilities when developing integrated solutions. The innovation possibilities certainly exist. They can take the form of architectural innovation, in the form of new combinations of elements such as services and products. However, it is also possible for all the elements to be radically redeveloped in order to fulfil customer needs (see Kim and Maubourgne, 1997; Ehrenfeld and Brezet, 2001). Unfortunately, it was more common for new services to be developed as add-ons to products than for the companies to explore the innovation potential in the product, the service, user behaviour and the delivery of solutions (see Figure 7.2).
7.4 Include environmental considerations in the project selection process

Including environmental evaluation in project selection is important because of the role of environmental performance in business strategy. For companies whose level of ambition is to ensure that they meet all legal requirements, the environmental aspects are easy to evaluate at a project selection stage. They are mandatory and non-negotiable. These companies need to ensure that the legal requirements are known and considered when turning ideas into project proposals.

For companies whose business strategy moves beyond merely fulfilling legal requirements, the selection process and the stage of product development where the business case is investigated become more open to environmental innovations. Environmental performance can be one of the evaluation criteria to be used when selecting projects. The market potential is, of course, also of great importance and so is how consumers’ value environmental performance.

These recommendations are presented as a three-step procedure to be performed in the early stages of product development, that is, when making the first business case investigation of ideas and when selecting which ideas to realize.

1. Investigate the environmental potential of projects along with their market and technical aspects.

The environmental potential of a product should be considered when business cases are investigated in the early stages of product development. Not only must legal requirements be met, but when undertaking projects that involve radical innovation, there may be considerable potential to improve environmental performance.
2. Environmental performance should be one of the evaluation criteria in the project selection process. Mandatory fulfilment of legal requirements is the lowest level to be considered.

It is mandatory to fulfil legal demands, but if a company is to be more proactive and achieve environmental targets that surpass the legal requirements, these targets must be perceived as strategically important. A clear environmental direction needs to be included in the business strategy. One way of communicating this clearly is by having environmental performance targets for products.

3. Environmental performance targets needs to be clearly described in the project description so that they are included when developing the product specifications.

Including the environmental performance targets at this level guides the product development process and the target-setting process for products.

7.5 Set environmental targets

Four procedures for setting environmental targets for products were identified in studies III, IV and V. They are useful for different purposes and all have advantages and disadvantages. Manufacturing companies should evaluate which procedure to use. EMS can be a tool to be used in setting environmental targets for products. One important, though difficult, aspect of target setting is ensuring that targets are clear and measurable. Environmental considerations should be given clear status in the company, for example, by making them the responsibility of a well-known and highly regarded person. Managers and projects members can then easily turn to that person when balancing requirements or when there is a need to resolve questions about environmental targets.

Companies also need to consider how to set environmental targets for services and integrated solutions. However, this process was not studied in detail in the research presented here.

- Breaking down environmental targets for each project separately from a product identity

This procedure is useful for clarifying the environmental performance targets at a strategic level. It is connected to consumer perception and the business strategy and is a good way of communicating the environmental strategy for products both externally to customers and internally.

- Setting targets for prioritised business areas at a business level for each project separately

This procedure is beneficial when strategic characteristics of a product are also considered to be significant environmental aspects. The environmental level is regulated in an EMS and business decisions can be taken for each product. This
Conclusions: How to modernise ecodesign

approach allows scope for taking advantage of innovation potential by setting challenging targets at a strategic level early in the project.

- **Developing the level of the environmental targets in the project development team**

  When aiming for redesign and acknowledging and embracing the environmental possibilities, it is important to set proactive targets at a business level and also to create commitment in the project team. Find the innovation potential and consider the environmental possibilities as well as the consumer aspects when setting targets. The team should be guided by an environmental strategic direction.

- **Developing ecodesign specifications to be used in all project**

  Pre-defined ecodesign specifications are useful to ensure that all legal requirements are met. They are especially suitable in refine and repair projects when the innovation potential is low. Designers can use them directly in the operational stages.

7.6 **Develop ecodesign procedures that fit the characteristics of the development process**

Ecodesign needs to be adjusted to suit the type of project being developed, since development processes differ.

For **redesign** projects, a traditional stage-gate processes is not always. The development process is iterative and exploratory. Environmental targets can be used to guide the project and ensure that environmental considerations are taken into account. One important factor in achieving large environmental improvements in redesign projects is that the environmental potential of solutions must be evaluated and embraced from the start of the project. Challenging environmental and performance targets should be set. Managers can also encourage environmentally beneficial solutions by giving positive feedback. The environmental performance of different solutions needs to be actively evaluated during the development process so that solutions fulfilling environmental targets are developed.

For **rethink** projects, the major difference is that ecodesign needs to be applied when developing total offers as well as when developing specific products. In study II, the product development process in the manufacturing firms was formalised but service development was often performed on an ad hoc basis, originating at different sales companies. The service development did become more formalised and centralised in the companies, although a desire for increased interaction between departments was still expressed. This desire arose from a need to understand how the products and services fitted together and to have a common picture of the customers’ needs. It was clear in study II that several of the companies did not acknowledge the environmental or innovation potential when developing integrated solutions.
The interaction between service development, product development, business development and the customer could be increased by applying the ideas and the business development model for integrated solutions proposed by Brady et al. (2004). The model fits well with the needs identified for the companies in study II. It proposes increased interaction between service units and products units and that a strategic centre handle the coordination between development units and sales and customer-facing units. The aim is to have a customer-focused process in which product and service development aim to develop parts that fit the integrated solutions.

The environmental activities recommended are also connected to the integrated solutions process described by Brady et al. (2004) (see also section 2.6). The five factors described above should be taken into consideration and applied to the business development process for integrated solutions. Figure 7.3 illustrates how environmental considerations can be integrated into a business solutions process.

Figure 7.3 Ecodesign when developing integrated solutions, which can be seen as a rethink approach (adapted from Brady et al., 2004).
Conclusions: How to modernise ecodesign

7.7 Critical review

Five studies were performed to answer the four research questions that address the two research objectives. Studies II to V were empirical studies. There is considerable discussion of how many companies should be studied and how many interviews should be conducted in order to answer a research question or fulfil an objective. When studying rethink, six companies were studied, but when studying the role of ecodesign in the early stages of product development and redesign, only two companies were studied. Given the small sample, the results should not be seen as statistically significant. However, the aim has not been to focus on a large number of cases but rather to use an exploratory approach to describe a few cases in detail. Readers can learn from the cases described and can apply the knowledge to their own situation. The conclusions drawn should be considered by manufacturing companies and can be applied providing the specific context of each company is taken into consideration. On a general level, the recommendations are an instrument that manufacturing companies can use for evaluating and improving their own ecodesign work.

This thesis makes the following academic contribution:

- It combines traditional theories on the early stages of product development, innovation and integrated solutions with ecodesign theory. Empirical studies have been analysed using both non-environmental and environmental theories in order to understand how ecodesign should be performed in companies.
- It reports on empirical studies of the strategic early stages of product development and for redesign and rethink projects. The ecodesign literature often recommends that environmental considerations be taken into account in such projects, but there has thus far been little study of the processes involved. Recommendations are made on the basis of the empirical data and of theory.

This thesis makes the following contribution to industry:

- The recommendations can be used to identify areas for improvement and to review ecodesign work in a company,
- The recommendations and procedures can be implemented to improve and modernise ecodesign in the strategic processes in early development, such as during project portfolio selection and target setting. They can also be used in the development process when aiming for innovative products and integrated solutions.

Most of the data on which these recommendations are based was collected in interviews. When conducting research and performing interviews in an area such as ecodesign, one needs to be careful when interpreting the answers. To be environmentally friendly is regarded as politically correct, and respondents may, intentionally or unintentionally, convey a more positive view of environmental work than their actual view as reflected in their work. Thus all responses need to be treated
with caution. Moreover, many of those interviewed were environmental managers, who may have a different view of the environmental work in the company than, say, design engineers. The author has done her best to bear these points in mind when analyzing the results. Non-environmental experts were also interviewed in order to get a more diversified picture.

7.8 Further research

Further research is needed in the following areas:

- How to develop environmental targets that are easy to use in product development.
- The environmental possibilities of different rethinking strategies for companies.
- How to support companies in developing integrated solutions that take environmental concerns into account in a rethink approach.
- Consumer aspects and user behaviour aspects of rethink approaches.
- How EMS can be used to modernise ecodesign in manufacturing companies.
- How to generate the driving forces that will push companies to develop products and services that take account of environmental concerns. This may be the most challenging problem of all.
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