Strategic Sustainable Product Development - A Case of an SME in the Sealing Industry

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Abstract: Product development is a crucial leverage point to move our society towards sustainability. The purpose of this study is to gain knowledge on how a selected strategic tool for sustainable product development (SPD), namely the Method for Sustainable Product Development (MSPD), can be adapted to integrate sustainability aspects into the Product Development Process (PDP) of an organization. A Small and Medium Sized Enterprise (SME) in the manufacturing industry with customers and office locations worldwide is used as a case study. A participatory action research approach is used throughout the study. It is shown in the case that the MSPD triggers thinking in product development by raising sustainability-related questions. In order to be answered most questions, however, require additional sustainability education in the organization and further investigation in long-term, company-wide projects, which the current PDP of the organization was not designed to provide. It was concluded that iterations of the process with the integrated MSPD tool and additional tools to supplement the MSPD are necessary to further move product development at the organization towards sustainability.

Keywords: Product Development, Sustainable Product Development Tools, Method for Sustainable Product Development, Framework for Strategic Sustainable Development.
Statement of Contribution

This thesis was a truly collaborative effort from all three team members bringing their respective strengths and perspectives to the process.

Due to the close collaboration with an organization and utilization of participatory action research, much of the work was conducted with all group members present and contributing.

During the literature review and writing of the thesis paper, the work was evenly divided taking into account our backgrounds and strengths to ensure the most productive progress. Each of the group members significantly and equally contributed to the final outcome.

All members reviewed and revised each other’s work and contributed to all aspects of the thesis.

The experience of writing a group thesis yielded far stronger results than any attempt to do so individually might have done.

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Anna Barkan
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Executive Summary

Introduction

In order to reach sustainable development there is an urgent need for a profound change in the way we live in society. Product development plays a significant role in moving our society towards sustainability, as products currently actualize many of our needs. Taking a sustainability perspective in a product development process has a great influence on the social and environmental impact of the product. It is, therefore, essential to develop methods and tools for sustainable product development.

When considering sustainable product development tools, one should make sure that the tool entails environmental, social, as well as, economic aspects in order to adopt a full sustainability perspective. However, most of the available tools do not include social aspects, are limited to specific environmental impacts of products and do not include how these fit into a viable strategy towards a sustainable society. There is lack of tools for sustainable product development.

Having identified this lack of tools for sustainable product development, a group of researchers at Blekinge Institute of Technology adapted s Strategic Sustainable Development approach for product development, resulting in three tools: the Method for Sustainable Product Development (MSPD), the Templates for Sustainable Product Development (TSPD) and the Strategic Life-Cycle Management (SLCM) Matrix.

To guide this study the following research question has been developed:

How can a selected strategic tool for sustainable product development be adapted and integrated into the product development process of an SME in the sealing industry?

The organization investigated in this study is the sealing manufacturing small and medium-sized enterprise (SME), Roxtec International AB, that has customers in various business sectors and office locations worldwide. The headquarters of Roxtec is located in Karlskrona, Sweden.
**Methods**

The research process for this thesis is divided into three distinct phases:

**Initial Descriptive Phase:**

- An initial descriptive study in order to describe the current product development process in the organization and the three strategic tools for sustainable product development.

**Prescriptive Phase:**

- A prescriptive study in order to select, adapt and integrate one strategic tool for sustainable product development into the product development process of the organization.

**Second Descriptive Phase:**

- A second descriptive study to apply the developed product development process in a test case within the organization and to evaluate whether the developed product development process and the results from the test case represent strategic moves towards sustainability for the organization.

While working closely with the organization we used Action Research that aims to bring theory and practice together in the pursuit of practical solutions. In this study we worked together with the organization and supported them with scientifically grounded tools to practically integrate sustainability aspects in the product development process of the organization. By co-creating our research with Roxtec we tried to increase the commitment of the representatives involved in the product development and thereby increase the likelihood that the tool will be used in the future. The participation of Roxtec in our research was carried out through workshops and interviews. Moreover, we constantly proposed different ways to proceed and checked back with the organization if they felt this was appropriate or if they liked us to follow a different approach.

The specific working methods used in this study included:

- A mapping workshop to map out the current product development process of the organization in the initial descriptive phase;
- A criteria workshop to define criteria for the tool selection and adaptation in the prescriptive phase;
- A tool integration workshop to integrate the selected and adapted tool to the organization’s product development process in the prescriptive phase;
• Application of the new process in a test case in the prescriptive phase; and,
• Interviews to evaluate the process in the second descriptive phase.

Results

The MSPD, TSPD and SLCM Matrix were evaluated against criteria developed through the criteria workshop with Roxtec. MSPD’s flexibility, possibility to prioritize according to business aspects and its potential to trigger creative thinking put the tool in the lead compared to the other two tools. Therefore the MSPD is the selected tool for this study.

An overview of the mapped product development process of the organization was obtained from the initial descriptive phase. The dashed boxes indicate the components of the MSPD tool that were incorporated into the product development process during the tool integration workshop in the prescriptive phase. The most prominent components is the MSPD checklist in the Pre-Study phase of the product development process.

Inclusion of Sustainability Aspects in Mapped PDP.
Based on the adaptation of the MPSD tool and the input during the tool integration workshop, an MSPD checklist was constructed.

![MSPD Checklist Structure](image)

**Illustration of MSPD Checklist Structure.**

**Discussion**

The questions in the MSPD proved to encourage the user to think in new ways that allowed a wider perspective to sustainability and to re-evaluate the routines and common practices within the organization in that context. Most of the questions, however, required more sustainability related education and input from all entities in the organization in order to be able to develop applicable answers to them. Being a tool focused on raising important questions, the MSPD itself does not provide the organization with answers. Different options to deal with this kind of questions might be to:

- Extend the current product development process to include its wider organizational interactions;
- Set up an additional product development process bridged with other organizational processes dealing with questions that require long-term investigation; and/or
- Create a department that is focusing on these long-term investigation questions.
Furthermore, the integration of an overview tool in the beginning of the product development process would be an asset. For further investigation into the checklist questions various more comprehensive tools could also be useful.

The use of participatory action methods engaged the organization in the development of all aspects of the thesis and the outcome was truly a co-creative process. This working method served as an effective process for integrating a strategic tool for SPD into product development process when working with an organization.

**Conclusion**

Raising sustainability-related questions through the MSPD integrated product development process should be regarded as an initial step towards sustainability for Roxtec, since it creates awareness and makes the designer actively incorporate sustainability aspects into design decisions. This step is insofar strategic as the organization can now build upon it, and as a next step, investigate more into the questions in long-term, company-wide projects.
Glossary

**ABCD-Analysis** – a strategic tool that uses backcasting from basic sustainability principles. The ABCD can be seen as the step-by-step manual on how to use the FSSD for planning.

**Backcasting** – a planning methodology based on envisioning a successful future and working backwards to connect this future to the present.

**BOS - Business Opportunity Specification** – a document used at the organization in question to outline the business case and brief description of a new product idea.

**EPC - Event Driven Process Chain** – a type of flowchart used for business process modeling.

**FSSD - Framework for Strategic Sustainable Development** – a framework, based on systems thinking and analysis from a whole system perspective, that supports planning in complex systems.

**MSPD - Method for Sustainable Product Development** – a strategic tool for sustainable product development, intended to be used by organizations to develop more sustainable products throughout the whole product development process.

**PDP - Product Development Process** – the process of developing new products.

**PS - Project Specifications** – a document used at the organization in question to outline detailed technical, business and project requirements for a new product development project.

**RoHS - Restriction of Hazardous Substances directive** – a directive that restricts the use of certain hazardous substances in the manufacturing of various types of electronic and electrical equipment.

**ROI - Return on Investment** – the ratio of money gained or lost (whether realized or unrealized) on an investment relative to the amount of money invested.
SME - Small and Medium Sized Enterprise – an enterprise which employs fewer than 250 persons or 500 persons depending on the local standards.

SLCM Matrix - Strategic Life Cycle Management Matrix – a strategic overview tool for sustainable product development intended to be used by organizations to get a high level summary of sustainability aspects of a product throughout its life cycle.

SPD - Sustainable Product Development – a process that embeds both responsibility and concrete issues of environmental, social and economic sustainability in the development of new products.

SPs - Sustainability Principles – principles built upon scientifically rigorous, consensus-based understanding that define the minimum conditions for a sustainable society.

TSPD - Template for Sustainable Product Development – a strategic overview tool for sustainable product development, intended to be used by organizations to initiate out-of-the-box thinking and expert dialogues regarding sustainability in the product development.
# Table of Contents

*Statement of Contribution* ......................................................... ii

*Acknowledgements* ...................................................................... iii

*Executive Summary* ................................................................... iv

*Glossary* ................................................................................... x

*Table of Contents* ....................................................................... xii

*List of Figures* ............................................................................... xv

1  *INTRODUCTION* ........................................................................ 1

1.1 Sustainability Challenge and Product Development .............. 1

1.2 Tools for Sustainable Product Development ....................... 2

1.3 Strategic Tools for Sustainable Product Development .......... 3

1.4 About the Case: Organization Background ......................... 6

1.5 Aim and Scope ...................................................................... 10

2  *METHODS* ............................................................................. 11

2.1 Research Method ................................................................... 11

2.2 Interacting Methods with Case Study Organization .............. 12

2.3 Research Steps ...................................................................... 14

   2.3.1 Step 1: Mapping the Current Product Development Process 14

   2.3.2 Step 2: Describing Strategic Tools for Sustainable Product Development ............................................. 16

   2.3.3 Step 3: Selecting and Adapting a Strategic Tool for Sustainable Product Development ................................. 16
2.3.4 Step 4: Integrating the Selected and Adapted Strategic Tool for Sustainable Product Development into the Current Product Development Process ....................................................... 18

2.3.5 Step 5: Applying the New Product Development Process to a Test Case within the Organization ...................... 19

2.3.6 Step 6: Evaluating the Test Case and the Potential Move of the New Product Development Process towards Sustainability .............................................................................. 19

3 RESULTS ......................................................................................................................... 20

3.1 Step 1: Organization’s Current Product Development Process ................................................................................................................. 20

3.1.1 A Synthesis of Three Theoretical PDP Models ................. 20

3.1.2 Mapped PDP of the Organization ........................................ 22

3.2 Step 2: Overview of the Strategic Tools for Sustainable Product Development ...................................................................................................................... 26

3.2.1 Method for Sustainable Product Development .............. 26

3.2.2 Template for Sustainable Product Development .......... 28

3.2.3 Strategic Life Cycle Management Matrix ...................... 29

3.2.4 Relationship between the Strategic Tools for Sustainable Product Development ................................................................. 30

3.3 Step 3: Selection and Adaptation of the Strategic Tool for Sustainable Product Development ................................................................. 32

3.4 Step 4: Integration of the Selected and Adapted Strategic Tool for Sustainable Product Development into the Current Product Development Process ................................................. 37

3.5 Step 5: Test Case of the New Product Development Process in the Organization ................................................................. 41
3.6 Step 6: Evaluation of the New Product Development Process

4 DISCUSSION

4.1 Research Question

4.2 How can…

4.3 … a selected strategic tool for sustainable product development

4.4 … be adapted

4.5 … and integrated

4.6 … into the product development process

4.7 … of an SME in the sealing industry

5 CONCLUSION & FURTHER RESEARCH

5.1 An Effective Method to Work with Organizations

5.2 MSPD Questions as a Checklist for the Product Designer

5.3 A Long-term, Organizational-wide Effort for Answering the Questions

5.4 An Initial Step to Further Move towards Sustainability

5.5 Closing Remarks

References

Appendices
List of Figures

Figure 1.1: Generic Roxtec Cable Sealing Solution ......................................................... 6
Figure 2.1: Overview of Research Method ........................................................................ 12
Figure 2.2: Post-it Note Format for the Mapping Workshop ........................................ 15
Figure 3.1: Generic Product Development Process Phases for Mapping Workshop ............ 21
Figure 3.2: Roxtec´s Mapped Product Development Process Overview ......................... 22
Figure 3.3: An Excerpt of Triggering Idea Phase in Mapped Product Development Process ..................................................................................................................... 23
Figure 3.4: An Excerpt of Project Set Up Phase in Mapped Product Development Process ......................................................................................................................... 24
Figure 3.5: An Excerpt of Pre Study Phase in Mapped Product Development Process ......................................................................................................................... 25
Figure 3.6: Schematic Illustration of the MSPD ............................................................. 28
Figure 3.7: The Three Templates of TSPD (Based on Ny et al. 2008) .............................. 29
Figure 3.8: Strategic Life Cycle Management Matrix ..................................................... 30
Figure 3.9: Relationships between MSPD, TSPD and SLCM Matrix ............................ 31
Figure 3.10: Structure of Adapted MSPD Tool ............................................................. 36
Figure 3.11: Illustration of MSPD Checklist Structure .................................................. 39
Figure 3.12: Prioritization Matrix .................................................................................... 40
Figure 3.13: Inclusion of Sustainability Aspects in Mapped PDP .................................. 41
Figure 4.1: The PDP Bridged with Other Organizational Processes .............................. 53
1 INTRODUCTION

1.1 Sustainability Challenge and Product Development

A sustainability challenge is facing mankind. Some of the more recent and most influential reports on different types of the sustainability challenge include the Stern report (Stern 2006), the report on Millennium Ecosystem Assessment (Millennium Ecosystem Assessment (MA) 2005), the report of the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change 2010), and The Economics of Ecosystem & Biodiversity (TEEB 2010).

Although most of the above-mentioned reports focus on specific environmental or social impacts, in summary, all hint at the fact that in order to reach sustainable development there is an urgent need for a profound change in the way we live in society. We are constantly moving towards a situation where we become systematically more dependent on an ever-increasing demand for resources. This increasing demand at the same time has to be satisfied with a systematically decreasing availability of those resources. Moreover, the use and processing of those resources is - through complex cause-and-effect networks - the root cause for symptoms like climate change, eutrophication, deforestation, overfishing, etc. Some of those symptoms will soon be irreversible (Rockström et al. 2009).

Product development is expected to play a significant role in moving our society towards sustainability, as products currently actualize many of our needs. During product development, decisions are taking place to, directly and indirectly, determine what resources and processes are required to manufacture a product. Taking a sustainability perspective in an early stage in a product development process (PDP) has a great potential to influence the social and environmental impact of the realized product. It is, therefore, essential to develop methods and tools for sustainable product development (Charter and Chick 1997; Ritzén 2000).
1.2 Tools for Sustainable Product Development

There is a vast amount of scientific literature on integrating sustainability into product development in organizations. Going back in time, the development of tools started around the end of the eighties. In 1997, Baumann (2000) tried to map all the tools she could find in papers, mainly in business and engineering related journals. She counted more than 150 different tools of varying shapes and sizes in her literature review. And it should not be assumed that the number of tools has decreased over the last ten years, but rather increased exponentially.

Many of the tools are based on overarching concepts in the sustainability field. Some of the more prominent concepts are Industrial Ecology (Graedel and Allenby 1995), Factor 10 (Schmidt-Bleek 1997), Cleaner Production (Aloisi de Larderel 1998), Natural Capitalism (Hawken and Lovins 1999), the Ecological Footprint (Rees and Wackernagel 1994), Zero Emissions (Pauli 1998; Suzuki 2000) and Ecodesign or Design for Environment (Tischner et al. 2000; Fiksel 2009).

The transition from concepts to tools is rather fluent and not strictly defined. While the amount of overarching concepts is manageable, the number of tools keeps increasing at an overwhelming rate. To provide an idea of the vast number of tools available, a rather arbitrary collection of tools is listed below, which by far does not claim completeness:

When considering sustainable product development tools, one should make sure that the tool entails environmental, social, as well as, economic aspects in order to adopt a full sustainability perspective (Brundtland 1987). It has been widely adopted in scientific literature that these three pillars build the foundation of any sustainable development (e.g. Barbier 1987, Elliot 2006 or Rogers et al. 2008). Often tools are labeled as ‘green’, ‘eco’ or ‘sustainable’ interchangeably even though only one or two of these aspects are included (Madge 1997). Most of the above mentioned tools do not include social aspects, but are limited to specific environmental impacts of products and do not include how these fit into a viable strategy towards a sustainable society (Byggeth and Hochshorner 2006). This means that there is lack of tools for sustainable product development (SPD) (Byggeth et al. 2007).

1.3 Strategic Tools for Sustainable Product Development

Being strategic involves working backwards from a defined success and developing a path that would lead from the present to a successful future, otherwise known as backcasting (e.g. Robinson 1990). In order to be strategic one must know the goal that needs to be achieved. For complex systems this goal should be described at a principled level, or, in other words, using success principles. These principles should describe the goal in a basic, but operational manner. For example Ny and colleagues (2006), Robèrt and colleagues (2007) state that such principles should be:

- based on a scientifically agreed upon view of the world,
- necessary to achieve sustainability
- sufficient to cover all aspects of sustainability
- concrete enough to guide actions and problem solving, and preferably
- mutually exclusive to facilitate comprehension and monitoring.

Describing a successful goal on a principled, and not detailed, level makes it easier to build consensus in teams about early steps and investments that are flexible and economic with regard to possible forthcoming routes. Those can then be further explored as the unfolding of the planning and practices that bring more knowledge and experience to the planning process. It resembles chess where each move should strike the right balance
between moving toward the principles of checkmate in a flexible way on the one hand, and have an economic attitude towards saving pieces on the other. To discover such moves and re-evaluate them as the game unfolds, sticks out as more feasible than to try to foresee prematurely how checkmate will look like in detail. Knowing basic principles of success allows for an open ended, yet strict intellectual process. This way of sustainable development also facilitates communication among individuals with different functional or disciplinary backgrounds when developing strategies that would lead to the goal. Furthermore it makes it possible to deal with multi-dimensional trade-offs between different alternative measures and investments. Those are evaluated, not mainly with regard to pro’s and con’s in the short term, but with regard to their capacity to serve as platforms to forthcoming steps towards a situation when the principles of the goal are complied with and the trade-off no longer exists. In summary, one could say, robust principled definitions of goals make it possible to co-create, across disciplines, sectors and departments, strategic paths towards endgames in an open ended, yet strict way (Holmberg and Robért 2000). For the complex system of the ecosphere the following four Sustainability Principles (SPs) were derived (Holmberg and Robért 2000, Ny et al. 2006):

*In the sustainable society, nature is not subject to systematically increasing...*

1... *concentrations of substances extracted from the Earth’s crust.*
2... *concentrations of substances produced by society.*
3... *degradation by physical means.*

*and, in that society...*

4... *people are not subject to conditions that systematically undermine their capacity to meet their needs.*

Around these four SPs, a framework for planning in complex systems was developed (Robèrt 2000, Robèrt et al. 2002). Applied to society in the ecosphere, this framework is called Framework for Strategic Sustainable Development (FSSD). Planning in complex systems requires an approach or framework based on systems thinking and analysis from a whole system perspective. If tackling each symptom separately and on its own in a reductionist manner, we will not likely be able to move our society towards
sustainability. Instead a ‘simplicity without reduction’ approach (Broman et al. 2000) should be used, which the FSSD is based on.

The FSSD suggests five levels for planning how to strategically move our society towards sustainability (Robért 2000):

1. The **System level** defines the functioning system, including the constituent components and processes within it. In this case, the system is the ‘society in the biosphere’ or ecosphere.
2. The **Success level** defines success for the system, in this case - sustainability. Success is hereby defined using the four basic SPs as mentioned above.
3. The **Strategy level** describes how to reach success in the system. It provides generic guidelines needed for society and organizations to move towards sustainability. As mentioned above, it is constructed by backcasting from success as defined based on the four SPs.
4. The **Action level** describes specific measures that can be chosen to fit the strategic guidelines and put into business programs designed to reach success in the system. Actions to strategically move the society towards sustainability could include a range of options from switching to renewable energy to education to providing food and shelter to those in need.
5. The **Tools level** entails tools that can be used to support any of the above-mentioned levels. The ABCD-analysis (Holmberg and Robért 2000; Robért 2000) is one example of a strategic tool that can be used to backcast from the four SPs. Its steps include: (A) defining the system and its conditions, as well as, success in the system, (B) assessing the current reality of the system in relation to success, (C) developing actions and measures for the system to move towards success, and (D) strategically prioritizing the actions to develop a stepwise plan towards success. Tools for Sustainable Product Development help to realize the strategy by integrating sustainability aspects into product development and thereby supporting a societal move towards sustainability, i.e. success.

Applying the FSSD to product development, a research group at Blekinge Institute of Technology, Karlskrona Sweden, developed three different strategic tools for SPD: the Method for Sustainable Product Development (MSPD) (Byggeth 2001; Byggeth et al 2007), Templates for Sustainable
Product Development (TSPD) (Ny et al. 2008) and Strategic Life-Cycle Management (SLCM) Matrix (Ny et al. 2006).

1.4 About the Case: Organization Background

Organizational background

In this thesis we consider an organization as a case. This organization is a subsystem of the system ‘society in the biosphere’ (compared to level 1 of the FSSD). In order to move society towards sustainability it is necessary that organizations embedded in the larger system, ‘society in the biosphere’, operate in a sustainable way and offer products that consumers can use in a sustainable manner. The organization investigated in this thesis is Roxtec International AB, which is a small and medium-sized enterprise (SME). It is a sealing manufacturing organization with customers in various business sectors and office locations worldwide. The headquarters of Roxtec is located in Karlskrona, Sweden.

A generic cable sealing solution developed by Roxtec entails a frame in which layers of modules, stayplates and a wedge are positioned (see Figure 1.1).

![Figure 1.1: Generic Roxtec Cable Sealing Solution](image)

The wedge serves as a compression unit which, by turning the screws in the front, compresses or decompresses the modules. The stayplates anchor the modules axially in the frame and thus prevent the modules from slipping.
The wedge clip ensures that the bolts in the wedge are completely tight and the lubricant helps to set the layers more easily. As a whole the solution provides protection, such as leakage tightness and fire barrier, as necessary, through the wall along the cables. Requirements on how resistant the solution is against water, pressure and fire differ in the various applications. According to the different applications additional technical requirements may be added.

Identification of key organizational ‘Sustainability Packages’

Prior to this thesis, the FSSD was introduced to the organization and an ABCD-analysis was completed together with its representatives (Postel et al. 2009). As part of the process, an envisioned future was developed that represents success for the organization within the frame of the four SPs (level 2 of the FSSD). Subsequently, a baseline analysis was performed detecting the current sustainability gap of the organization. By backcasting from the successful future, a list of measures that could help the organization to move towards its envisioned future was co-developed (level 3 of the FSSD).

Moreover, the measures developed were prioritized and bundled to form seven sustainability packages which if fulfilled would represent stepping stones towards sustainability for the organization. Each sustainability package represents a specific area of business for the organization, yet all seven combined are expected to be required for a systematic move towards sustainability:

- **Motivate a Dream**: set a common goal to strive for sustainability to be pursued by the company as a whole and by each employee individually.
- **Become Carbon Neutral**: optimize transportation of goods and people.
- **Simply Produce**: aim for a streamlined production process that uses no hazardous chemicals.
- **Rethink Energy**: focus on energy efficiency and renewable sources.

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• **Rely on Supply**: establish close cooperation between the organization and lead suppliers, co-creating a sustainability agenda.

• **Grow Service**: instead of selling a product to the customer, use the product to sell service agreements.

• **Innovate Green**: develop products that are easy to disassemble after use and made of only few different types of materials which are recyclable and/or degrade naturally.

The seven sustainability packages represent seven distinct sectors within the system of the organization. ‘Motivate a Dream’ deals with the employees within the organization. ‘Become Carbon Neutral’ and ‘Simply Produce’ address the logistics and production activities, respectively. Input to those activities is represented by ‘Rethink Energy’, which deals with the energy input and ‘Rely on Supply’ that deals with the input from suppliers. And finally ‘Grow Service’ and ‘Innovate Green’ address the output including the use and end of life of the product divided into two generic industry sectors. Thus, the combination of the seven sustainability packages represents the full value chain of the organization. All sustainability packages are required for the complete move towards sustainability for the organization. They all entail short-term, long-term, simple and more comprehensive actions (level 4 of the FSSD).

**Starting with the ‘Innovate Green Sustainability Package’**

As an initial step, with the intent to be followed by more comprehensive and potentially long-term measures, the sustainability package ‘Innovate Green’ was chosen by Roxtec to be expanded upon and it represents the basis of this thesis.

With ‘Innovate Green’ we recognized that one of the major sustainability challenges that the organization will face in the future would be the lack of control regarding the disposal of its products after use. This might lead to filling landfills (SP3) or accumulation of substances produced by society (SP2) and thereby harming the environment. Roxtec therefore, among other things, has to make sure that the products it sells are easy to disassemble after use and made of only few types of materials which either are recyclable or degrade naturally. We will attempt to achieve this with the integration of sustainability aspects into the PDP of the organization.
From a business perspective ‘Innovate Green’ could likely secure competitive advantage and future growth for the organization. The organization is expected to be able to extend its product range through new innovative products, generating new patents to supplement its current pool of patents. Furthermore, the organization could deliver products that would better suit the specific requirements of different applications regarding lifetime, flame retardancy, etc. It would not serve all customers and all markets in a ‘one product fits all’ manner. This flexibility in product choice could further enhance customer satisfaction. Last but not least, from a business perspective, the organization could enter new markets in which customers continuously become more environmentally conscious. These business advantages have been found as being generic and important stimuli for SMEs to adopt eco-design in their product development (Hemel and Cramer 2002).

Finally it should be mentioned that integrating sustainability aspects into the organization’s PDP could lead to products that support completely new services which are required in a sustainable society. It could also lead to the development of new types of services that meet the same needs that are currently met through the sealing solutions. Both could introduce new markets for Roxtec.
1.5 Aim and Scope

In this thesis we will initiate the ‘Innovate Green’ sustainability package and try to integrate sustainability aspects into the PDP of the organization, starting with one of the tools that is based on the FSSD. Regarding the five level framework shown earlier we will, thus, focus on the tools level (level 5 of the FSSD).

The purpose of this thesis is formulated as:

To assess whether a strategic move towards sustainability could be triggered by integrating a selected strategic tool for sustainable product development into the product development process of an SME.

And to guide this study the following research question has been developed:

How can a selected strategic tool for sustainable product development be adapted and integrated into the product development process of an SME in the sealing industry?

This thesis also relates to the ‘Real Change’ program, an international partnership between Blekinge Institute of Technology (BTH) in Karlskrona, Sweden, Lund University, The Natural Step International and other research institutions, that examines the science behind sustainable development together with businesses, NGOs, communities and policy makers (The Natural Step 2010). A subprogram named ‘Sustainable Product Innovation Research Initiative’ (SPIRIT) is located at BTH and aims to integrate the FSSD with product development and to develop a sustainable product-service system methodology including modeling and simulation tools (Real Change 2010). An expected concrete contribution of this thesis to the research conducted at BTH will be the actual application of the selected and adapted tool to an organization. Through this, information will be gained on how valuable the tools can be, particularly in terms of practicality, and what future research might be necessary to further optimize the selected tool.
2 METHODS

2.1 Research Method

Limited research is available on how to conduct research in the field of product design and development (Blessing 2002 or Blessing and Chakrabarti 2009). Only few papers mention how to proceed with it (e.g. Antonsson 1987 or Reich 1995). Thus, there is a lack of a research methodology that is commonly used in this field. We will, to a great extent, follow Blessing’s approach in this thesis, as she has been one of the pioneers in the creation of such methodology. Based on her proposed methodology for conducting research on design and product development we divided our research process into three distinct phases (see Figure 2.1):

Initial Descriptive Phase:

1. The current PDP in the organization is understood and mapped out according to a theoretical process-mapping model.
2. Strategic tools for SPD (MSPD, TSPD, SLCM matrix) and their connection to each other are described.

Prescriptive Phase:

3. Based on organization specific requirements for the tools, one of the three tools described in Step 2 is selected and adapted.
4. Based on Step 3, the selected and adapted tool is integrated into the current PDP of the organization as mapped out in Step 1.

Second Descriptive Phase:

5. The PDP developed in Step 4 is applied to a product development case within the organization.
6. The developed PDP is evaluated by checking whether the new process represents a strategic move towards sustainability for the organization.
2.2 Interacting Methods with Case Study Organization

Practically speaking, during the thesis period our group worked closely with the organization. We worked directly with the Global Technology department, which is in charge of product development, as well as the Commercial Support department, which deals with customer service. As the organization’s headquarters is located in Karlskrona and is easily accessible, a significant amount of the time was spent at the organization’s office working directly with its personnel. The organization provided our team with a dedicated desk as well as a laptop to facilitate access to their information and documentation. We believe that the close relationship we developed through the project that was conducted with the organization prior to this thesis facilitated our research work (Maxwell 2005, 82). As Bosk noted, field study is a “body-contact” sports (Bosk 1979, ix) and we tried to live up to this notion.

Action Research

While working closely with the organization we partly touched upon a way of conducting research that has recently gained increasing attention. Action Research, Participatory Action Research or Interactive Research (Reason and Bradbury 2001; Nielsen and Svensson 2006). Reason and colleagues (2001, 1) state that there is no short answer to the question what Action Research is, yet, as a working definition, it can be stated as “a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes”. The basic idea is to bring theory and practice together in the pursuit of practical solutions. During this thesis study we worked together with the organization and supported them with...
scientifically grounded tools to practically integrate sustainability aspects in the PDP of the organization. We consider this research as being part of a pursuit of worthwhile human purposes, since there is a great sustainability challenge approaching mankind. This research might be regarded as a small step in the long path to move our society towards a sustainable future (see full description in Introduction, section 1.1). From co-creating our research with Roxtec we also hope to increase the commitment of the representatives involved in the product development and thereby increase the likelihood that the tool will be used in the future. The participation of Roxtec in our research was essentially carried out through workshops and interviews. Moreover, we continuously proposed different ways to proceed and check back with them if they felt this was appropriate or if they wanted us to follow a different approach.

Qualitative Research

Another general way of conducting research that we made use of is Qualitative Research (Denzin and Lincoln 1994). Qualitative Research entails various methods that involve an interpretative approach to the subject matter. (Denzin and Lincoln 1994, 2). In our research we mainly focused on the method of interviewing. In particular, we opted for semi-structured interviews (Lindlof and Taylor 2002) in which the researcher does not strictly follow a structured catalogue of questions, but lets the interview flow by using guiding open-ended questions.

As Maxwell (2005, 39) states that “[a]ny view is a view from some perspective”, we acknowledge the fact that our personal backgrounds might have had an influence on the way we conducted our research. Thus, it should be mentioned at this point that two of the researchers have an engineering background and one researcher has a business background. One of the engineers and the person with the business background have some three to four years experience working in the industry. Nationalities are Russian, Swedish and German.

In the following sections, we describe the methods that we used for each step of our research related to action research and qualitative research. We also include the way we tried to increase the validity of our findings by different means.
2.3 Research Steps

2.3.1 Step 1: Mapping the Current Product Development Process

The first step was to plan a workshop with the organization to understand and map the current PDP. For better understanding of the different steps that are involved in a PDP, a literature review of different theoretical product development models was conducted. The challenge was to provide the participants of the workshop with an idea of what a PDP entails for triggering a discussion, but at the same time, not to steer the participants in any one direction when mapping. In order to allow for this, commonalities of different theoretical models were identified, based on personal experience and literature review, to subdivide the generic PDP into several parts that would be used in the workshop to trigger thinking. In addition, using this method we gained a better understanding of what the participants were mapping out and were able to ask additional guiding questions when we felt they were struggling with the process or possibly overlooking particular aspects.

Selecting a mapping method

A study of mapping methods and their implementation with different software tools was conducted before the workshop. Benedictis and colleagues (2004) have evaluated how EPC (Event Driven Process Chain) (Scheer 1998) and IDEF0 (Integration Definition for Functional Modelling) work with the software tools ARIS, Visio Professional and PowerPoint. The EPC method was then found to be easy to understand and learn because it shows processes in a logical flow, by using events, activities, and connectors with ‘and’, ‘or’ or ‘and/or’ where these can also be extended with other figures, such as responsibilities, documents and tools (Benedictis et al. 2004). Visio with its resources for pre-defined objects, creating new objects, grouping objects and easily connecting them was the best software combination to the mapping methods. “The printed model shows adequate visual quality and the tool’s graphic interface is friendly enough: the best of them.” (Benedictis et al. 2004). Therefore, the EPC method and the Visio software were selected to document the PDP.
Mapping workshop

The mapping workshop was divided into two general sections: group work and discussion. The group work was subdivided into PDP phases and intended to provide the participants with an opportunity to brainstorm and roughly map out the current process that takes place during product development. Subsequently, a discussion took place to observe and review the outcome of the group work and for the participants to share their reflection of the dynamics and outcome of the mapping workshop.

Practically, during the group work the participants were provided with Post-it notes, writing utensils and a flip chart. Each Post-it was divided into three sections allowing the participants to input information regarding an action in the PDP, the individual or group responsible for the action, and the tool or document required for the action (see Figure 2.2).

![Figure 2.2: Post-it Note Format for the Mapping Workshop](image)

This structure facilitated the later input of the obtained information into the EPC structure. Using the provided materials, the participants were asked to produce a rough process map of the organization’s PDP. Once the PDP was mapped out, the outcome of the mapping workshop was presented and discussed by the participants. The results of the workshop were obtained and documented.
Follow-up interviews

Once the process was documented, interviews with the mapping workshop participants were conducted to verify the accuracy of the mapped PDP. Interviewees were selected based on expertise and involvement in a particular section of the PDP. Changes and corrections were made based on the input obtained in the interviews. By checking back through interviews, we aimed for higher validity of the current PDP in the organization.

2.3.2 Step 2: Describing Strategic Tools for Sustainable Product Development

Concurrently a research of the strategic tools for SPD was conducted. The research was also supported by interviews and discussions with BTH representatives who were involved in related subject matter previously or at the time of this study. This included representatives that were involved in previous collaboration work between Roxtec and BTH, the development of strategic tools for SPD or both.

2.3.3 Step 3: Selecting and Adapting a Strategic Tool for Sustainable Product Development

Criteria workshop

In order not to overload the organization with tools it was in this initial study decided to focus on one specific tool. A workshop was held with the Roxtec representatives, in order to engage them in the selection of the tool and thereby improving the chances for that the selected tool later on meets their expectations. The purpose of the workshop was to determine the criteria the tool should fulfil in the eyes of the organization, and therefore the workshop is further referred to as the criteria workshop. The criteria workshop was part of our Participatory Action Research approach and can be categorized as a semi-structured group interview with open questions. A few open questions to start were:

- What should we take into consideration in the adaptation of the product development process?
- What should we be careful about?
- What parts should not be changed?
• What is important for you in your personal work with the product development process?

Answers to these questions provided us with a first insight of important factors we should take into consideration when selecting a tool.

As requested by the organization we also presented some example tools in order to give participants an idea of what such tools could look like. We gave a quick introduction to three different tools in order to trigger further discussions among the participants regarding important factors for the organization. These tools were:

• Life-Cycle-Assessment (LCA) (Lindfors et al. 1995; ISO 2000; ISO 2006),
• Templates for Sustainable Product Development (TSPD) (Ny et al. 2008), and

We opted for these tools because they are very different in terms of time and expertise knowledge required, flexibility, ease of communication and quantitative data input. We did not present only the strategic tools for SPD in order to possibly trigger other important criteria that none of the strategic tools for SPD have. On the other hand, we decided to at least present one of the strategic tools for SPD in order to see which criteria might be particular for those. We felt, however, that any other combination of example tools could serve the same purpose as long as they are different enough to trigger discussions among the participants through comparison. Following an introduction of each tool we asked three questions:

• What do you like/dislike about the tool?
• Can you see yourself using the tool in PDP? Why/why not?
• Can you see yourself using parts of it? Why/why not?

Selecting and adapting

Based on the organization’s specific requirements the set of criteria to select the tool was determined and the selection was performed by matching each tool against each criteria. In order to make the selected tool fit even more with the organization’s requirements, it underwent some final
adaptations. Again, the idea was to increase the likelihood that the organization would make use of the tool after its integration.

2.3.4 Step 4: Integrating the Selected and Adapted Strategic Tool for Sustainable Product Development into the Current Product Development Process

After the selection and adaptation, the tool was integrated into the PDP of the organization. We again did this in a participatory process in which we, as researchers, together with employees involved in the product development co-created a PDP with sustainability aspects for the organization. The base for this was the map of the current PDP of the organization which we created in Step 1. This map shows in detail all activities that together represent the PDP. Furthermore it shows for each activity the responsible department, the tool in use, and the required document. With this knowledge it was easier to place the tool or its parts within the current PDP and by this we, together with the organization, created a PDP that is able to identify sustainability aspects. The tool that was finally selected was easy to subdivide into several parts. This, in turn, had an influence on how the integration of the tool was performed.

Tool integration workshop

A tool integration workshop was conducted to integrate the tool into the current PDP. During this workshop we first presented the selected tool to the participants. The rest of the workshop was held in the form of group work. For the group work the PDP map was projected against a whiteboard. Parts of the tool were separately given to the group on small pieces of paper. The participants could first discuss to better understand each respective part, and afterwards decided who would be responsible for this part and where in the map the respective part of the tool would fit best. When the discussion was finished, the piece of paper with the respective part written on it was posted with a small magnet against the whiteboard at the point where this part should be located in the PDP map. This procedure was repeated for all parts of the tool. If the participants felt that a part was in need of rephrasing for better understanding, or if they missed a part, they were invited to take a blank piece of paper and write their ideas down and follow the same procedure as with the other parts. Throughout the whole process participants were asked to group the different parts of the tool on
the whiteboard as required. Overall, the group work was open, as the intention was for participants to feel free to interact and use the whiteboard as they saw fit. The workshop was concluded with an invitation for a quick feedback from the participants regarding the process and the outcome of the workshop.

Follow-up interviews

Follow-up interviews were conducted to discuss additional details of the tool, as well as, verify that the outcome that was documented from the tool integration workshop was correct and accurate. The participants of the interviews were selected participants of the tool integration workshop, who play a major role in PDP projects in the organization.

2.3.5 Step 5: Applying the New Product Development Process to a Test Case within the Organization

After the integration of the selected and adapted strategic tool for SPD the new PDP was tested on a product development case. From discussions with the participants of earlier workshops and interviews at the organization an appropriate reference product was selected to test the new PDP. This product was going through the organizational PDP that was valid before this thesis.

2.3.6 Step 6: Evaluating the Test Case and the Potential Move of the New Product Development Process towards Sustainability

One test case can hardly be seen as sufficient and statistically sound evidence that the tool we integrated results in the development of a process that aims to produce more sustainable products. Even if we were successful in the test case, we cannot exclude the fact that this might have been due to influences other than that of the integrated strategic tool for SPD. In order to assess whether the developed process represents a strategic move towards sustainability for the organization, we conducted expert interviews. These experts included representatives from Roxtec and BTH. A semi-structured interview was carried out with each expert individually. Finally, the researchers themselves performed an evaluation.
3 RESULTS

3.1 Step 1: Organization’s Current Product Development Process

3.1.1 A Synthesis of Three Theoretical PDP Models

From personal experience and literature review, three theoretical models were explored for mapping the organization’s current PDP:

- Roozenburg’s Innovation Process (Roozenburg and Eekels 1991);
- New Product Development Process (Kahn 2004); and,
- Stage Gate Process (Product Development Institute Inc. 2010).

Even though the three models are quite different, commonalities can easily be found between them. A generic process with three phases was defined that includes concepts from all three models:

Idea phase

All three models include a phase that consists of idea generation and selection. Roozenburg’s first phase ‘Product Planning’ includes policy formulation and idea finding (Roozenburg and Eekels 1991). In the New Product Development Process the first two stages are ‘Idea Generation’ that is conducted using methods such as SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis or brainstorming, followed by ‘Idea Screening’ during which the ideas are evaluated based on specific questions (Kahn 2004). Similarly, Stage Gate Process involves ‘Discovery and Scoping’ stages, where opportunities for new products are discovered and a quick analysis of technical qualities and market projections is conducted (Product Development Institute Inc. 2010).

Design phase

This deals with the development of the idea into a product concept, testing the design and evaluating its production and market. Roozenburg calls this phase ‘Strict Development’ and includes production development, product designing and marketing planning in it (Roozenburg and Eekels 1991). For the New Product Development Process, the three stages – ‘Concept
Development & Testing’, ‘Business Analysis’ and ‘Beta Testing & Market Testing’ can be grouped to fit this general phase (Kahn 2004). Finally, Stage Gate Process classifies this phase as ‘Build Business Case’, ‘Development’ and ‘Testing & Validation’ (Product Development Institute Inc. 2010).

Realization or commercialization phase

The realisation (Roozenburg and Eekels 1991) or commercialization (Product Development Institute Inc. 2010) phase includes the beginning of the production of the new product and its launch into the market. The launch phase involves the least degrees of freedom to incorporating sustainability aspects. In general, as one progresses further in the PDP, the degrees of freedom for product adaptations also decrease whereas the cost and technical difficulty of product adaptations increase. Thus, changes at this late stage should be avoided (Ullman 1992).

Consequently, we decided that focusing on the idea and design phases would be sufficient for the initial introduction of sustainability into the organization’s PDP during the mapping workshop (see Figure 3.1).

![Figure 3.1: Generic Product Development Process Phases for Mapping Workshop](image-url)
3.1.2 Mapped PDP of the Organization

Based on the analysis of the theoretical models we divided the group work in the mapping workshop into an idea phase and a design phase. The three-hour workshop conducted at Roxtec’s headquarters in Karlskrona involved five of Roxtec’s personnel including: research & development director, design engineer, material specialist, project manager and customer service manager.

The information obtained from the mapping workshop was compiled and documented. Minor changes were detected through check-back interviews and the map was revised as necessary. The final map overview (see Figure 3.2) and detailed description of each phase are presented below. The complete PDP diagram in EPC structure is presented in Appendix A.

![Diagram of Roxtec's Mapped Product Development Process Overview](image)

*Figure 3.2: Roxtec’s Mapped Product Development Process Overview.*
Triggering Idea

This represents the first phase in the PDP in which the initial need for the new product is generated. It is generated either from an employee’s intuition in general, a market need or a customer need (see Figure 3.3). An example for such a trigger would be a visit to the customer’s site or an idea from the market segment department.

![Diagram](image)

*Figure 3.3: An Excerpt of Triggering Idea Phase in Mapped Product Development Process.*

Business Opportunity Specification

When the need is identified, regardless whether it originates from a market or a customer need, a Business Opportunity Specification (BOS) is created. The BOS is an initial overview document that briefly describes the need and business case for the new product. It becomes the basis for making the decision whether to proceed to the next phase (Project Set Up). This decision point is indicated as Gate 1 in the PDP map (see Figure 3.2). The BOS includes a description of the basic function of the product, i.e. the product idea or the problem that needs to be addressed. The BOS also includes a description of market and geography involved, the potential of the idea, the potential customers, the target price, and whether the product may have any negative influences on existing products or if it would be complementary to the existing products.

When the decision takes place to approve or reject the BOS, an approval can also include a request for more specific concept identification. If a concept is requested, a rough prototype and simple drawings are created and the information is used to update the BOS before moving to the next phase. In special cases, the need may be generated from intuition and the idea would be directly discussed with the project manager. If the product idea is agreed upon with the project manager, no BOS needs to be created and the process may go directly to the next phase, Project Set Up.
Project Set Up

This phase includes a prioritization among the different BOS proposals and a decision on when to initiate each project (see Figure 3.4). Subsequently, a project team is created and a discussion takes place to clarify technical and project requirement before moving on to the next phase (Pre Study).

![Diagram of Project Set Up Phase in Mapped Product Development Process.]

*Figure 3.4: An Excerpt of Project Set Up Phase in Mapped Product Development Process.*

Pre Study

This is where technical and project requirements are analysed in more detail (see Figure 3.5). Technical requirements may include brainstorming, investigating materials, researching patents, drawing 3D models, rough prototyping, checking production capabilities and drafting a test plan. When materials are investigated, considerations such as the Restriction of Hazardous Substances directive (ROHS-directive) are taken into account, so that the product does not include any forbidden substances. Similarly for chemical lists, databases on the Swedish Chemicals Agency website[^2] are reviewed. Project requirements include preparation of an Authorization for Capital Expenditure (CAPEX), drafting a time schedule and allocating project resources.

[^2]: [www.kemi.se](http://www.kemi.se)
Project Specification

Based on the information from the Pre Study phase a Project Specification (PS) document is created that serves as a basis for the decision to move to the next phase, which is indicated as Gate 2 in the PDP map (see Figure 3.2). The project team now has a general idea of the product design and is ready to go into more detailed exploration. The PS document includes goal description, technical requirements and solution, supply chain considerations, test plan, description of roles and responsibilities, communication plan, related documentation, risk identification, estimated investments and costs, time plan and launch plan. When the PS is completed it is approved, rejected or sent for revision.

Supplier Identification, Risk Analysis, Pricing, Production Evaluation and Testing

Once the Project Specification is approved it is possible to move on to the final steps of the process. This section of the PDP includes five parallel
phases during which a risk analysis is performed (for example, failure modes and effects analysis (FMEA)), costs and pricing are explored for the product, the possibility to manufacture the product with existing production equipment is evaluated, possible suppliers are identified and prototypes are built to be tested for the requirements in the BOS and PS.

**Final Design**

The final design is frozen when suppliers are identified, risks are assessed, costs and pricing are explored, production is evaluated and the product is tested. After this phase documentation of the final design is produced and the product moves on to its realization.

**Summarizing the PDP mapping**

It is apparent that the current PDP of the organization includes limited exploration into sustainability aspects. The main sustainability aspects used are the Restriction of Hazardous Substances (RoHS) directive and the databases on the Swedish Chemicals Agency website. Therefore, there is a need to include further sustainability aspects in the PDP of the organization.

3.2 Step 2: Overview of the Strategic Tools for Sustainable Product Development

3.2.1 Method for Sustainable Product Development

Method for Sustainable Product Development (MSPD) is intended for use by product developers throughout the whole PDP. The method is based on the ABCD-analysis (see Introduction, section 1.3) and applies backcasting from the four SPs, which provides a strategic approach. It is built on a modular system of guiding questions that are derived by considering these principles over the product’s life cycle and throughout the PDP. Answers to the questions are evaluated against prioritization parameters.

In detail, the MSPD includes a manual and three different sub-tools. The MSPD manual relates to the A-step of the ABCD-analysis in that it provides the user with the objectives and theory of MSPD and instructions on how to use its different sub-tools. The three sub-tools are a Model of a Product Development Process, Sustainability Product Assessment (SPA) Modules and a Prioritization Matrix (see Figure 3.6):
The Model of a Product Development Process

This includes five phases: investigation of need, principal product, primary product, production process and launch and use. Each phase then includes general product development questions (PD questions) and guidelines for various aspects and they may also imply use of other tools, such as computer aided design (CAD), finite element method (FEM) and virtual reality (VR).

The Sustainability Product Assessment (SPA) Modules

These are divided into five modules: product function, product design, material type, production process and purchase. Each module includes strategic guiding questions to identify potentially critical substances and activities during the life cycle of the existing or planned product and questions to generate proposals for improvements. Together the questions cover the product’s life cycle, from raw material extraction to end of life. Each of the questions is divided into inventory-impact questions, relating to the B-step in the ABCD-analysis, and improvement questions from a backcasting perspective, relating to the C-step in the ABCD-analysis. Each of the questions is also connected to one or several of the SPs.

The Prioritization Matrix

This includes questions to facilitate evaluation and choice among proposals and the matrix is used after each PDP phase before continuing to the next phase. The proposals are listed in the matrix and the evaluation is based on answers to the following questions:

- Is the proposal technically feasible?
- Could the proposal be developed in a realistic time for the specific project?
- Can the proposal result in a good return of investment?
- Is the proposal environmentally adapted?
- Is the proposal a deliberate step towards sustainability?

---

3 A type of computer simulation using mathematical equations.
Sustainability aspects are integrated with traditional economic and technical aspects to improve the applicability of the method from a business perspective. The five questions are based on the D-step in the ABCD-analysis. The suggestion is to evaluate each question with four level grading and colours to facilitate illustration and communication within the project group (Byggeth et al. 2007).

![MSPD-manual](image)

**Figure 3.6: Schematic Illustration of the MSPD (Adapted from Byggeth et al. 2007).**

### 3.2.2 Template for Sustainable Product Development

The Template for Sustainable Product Development (TSPD) tool is complementary to the MSPD. The idea behind TSPD is that product development teams should arrive faster and more easily at an overview of the major sustainability challenges and opportunities of a product category in earlier development phases. The idea is also to facilitate creative communication between top management, stakeholders, and product developers. There are three templates (see Figure 3.7):

- **Template I** describes both current (corresponding to the B-step of the ABCD process) and future sustainable (C-step of the ABCD)
market desires, their relation to basic human needs and identification of the desired product function.

- **Template II** describes life cycle sustainability consequences of how both current and future sustainable product concepts meet market desires.
- **Template III** describes, both currently and in a sustainable future, what societal stakeholder consequences may arise from product concepts and how those consequences may be dealt with.

The issues covered by the three templates are considered to be particularly relevant for the creation of a generic overview. The D-step in the ABCD-analysis and the launch and realization phases of a PDP are all intentionally excluded in the TSPD, as the purpose is rather to trigger creativity and act as a quick overview input for later detailed priorities (Ny et al. 2008).

<table>
<thead>
<tr>
<th>TSPD</th>
<th>I. Need/ Function (Why)</th>
<th>II. Concept (How)</th>
<th>III. Extended Enterprise (Who)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Reality (B)</td>
<td>What current market desires is the product intended to meet?</td>
<td>Conceptual design of today’s product. Its flows and management routines from a sustainability perspective.</td>
<td>Current stakeholder communication and cooperation.</td>
</tr>
<tr>
<td>Desired Future (C)</td>
<td>What new market desires are likely to evolve?</td>
<td>Likely conceptual design of future product. Its flows and management routines from a sustainability perspective.</td>
<td>Likely future stakeholder communication and cooperation.</td>
</tr>
</tbody>
</table>

*Figure 3.7: The Three Templates of TSPD (Based on Ny et al. 2008).*

### 3.2.3 Strategic Life Cycle Management Matrix

Strategic Life Cycle Management (SLCM) is an approach that uses the SPs as a lens to evaluate product life-cycles, including raw materials, production, packaging and distribution, use and end of life (Ny et al. 2006). In practice, several concrete process tools are emerging from the SLCM theory (Ny et al. 2009). The process varies but they all revolve around a
sustainability performance matrix that scrutinizes violations of each of the four sustainability principles for each activity in the life-cycle (see Figure 3.8).

<table>
<thead>
<tr>
<th>SLCM Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Life Cycle stage</strong></td>
</tr>
<tr>
<td>Raw Materials</td>
</tr>
<tr>
<td>Production</td>
</tr>
<tr>
<td>Distribution</td>
</tr>
<tr>
<td>Use</td>
</tr>
<tr>
<td>End of Life</td>
</tr>
</tbody>
</table>

*Figure 3.8: Strategic Life Cycle Management Matrix*

### 3.2.4 Relationship between the Strategic Tools for Sustainable Product Development

The TSPD, the MSPD and the SLCM Matrix can be used in combination (see Figure 3.9). The quick and broad sustainability overview of the TSPD makes it suitable for early stages in the product development (primarily the need and concept phases), while the MSPD rather deals with design questions and can be applied throughout the whole PDP (Ny et al. 2008). Proposals for more sustainable product designs can later be prioritized along different parameters like for example return on investment. The SLCM Matrix is a supporting tool that may be used to evaluate alternative product concepts from a sustainability life-cycle perspective within the concept template of the TSPD (Ny et al. 2008). The matrix can also be used as a stand-alone tool for product sustainability assessments (Ny et al. 2006).
Figure 3.9: Relationships between MSPD, TSPD and SLCM Matrix (Based on Ny et al. 2008 and BTH Department of Mechanical Engineering 2008)
3.3 Step 3: Selection and Adaptation of the Strategic Tool for Sustainable Product Development

Criteria for selection and adaptation

Based on the criteria workshop the following criteria for the selection and adaptation of the tool were defined:

1. **Fast, easy and flexible**: These attributes particularly resonate with the core values of Roxtec and allude to the practicality of the tool. Fast and easy particularly means few resources should be required in order to integrate, use and maintain the tool.

2. **Part of the already existing process**: The tool should not be a stand-alone tool and there should be no parallel process. The tool should rather be integrated into the existing process.

3. **Business perspective**: The tool should show the return of the integration of a specific sustainability aspect. Added value is a major aspect in the decision-making within Roxtec.

4. **Trigger thinking**: The tool should support a creative process and help Roxtec to be innovative. The tool should aid the employees to open their minds and think in terms of sustainability.

5. **Ease of communicating results internally**: The results of the tool should be easy to understand for decision-making.

6. **Life-cycle perspective**: The tool should cover all life stages of the product.

7. **Valuation**: The tool should include an assessment if an aspect is good or bad in terms of sustainability.

Selecting the tool

In the following, we highlight only those criteria that finally helped us select the tool that we subsequently integrated. See Appendix B for the detailed description of how each tool performs against each of the criteria.

Regarding criterion number two, ‘part of the already existing process’, one should point out that the intention of the MSPD is to use it throughout the whole PDP. With its SPA modules of questions it creates a high level of flexibility and can be implemented at any stage of the PDP and, therefore, blends in well with the current PDP, as requested by Roxtec. In an earlier
investigation among some SMEs of how to integrate environmental aspects, Byggeth and Broman (2001, 270) found that the “tool must be a natural part of the ordinary product development process, if it is to be used at all”. The TSPD and the SLCM Matrix, on the other hand, are more difficult to be subdivided into parts to become a natural part of the organization’s PDP. They rather have to be integrated in their full scope, which inevitably leads to a parallel process or stand-alone tool.

Concerning criterion number three, ‘business perspective’, the MSPD is the only one of the three tools that in itself entails how an integrated sustainability aspect adds value to the organization. The Return on Investment (ROI) in the Prioritization Matrix directly shows the payback of different alternatives. Concerning the ‘valuation’ of different sustainability aspects, MSPD is also the only tool that helps to prioritize between different ideas with its Prioritization Matrix. The TSPD is intended to be used only for an overview. There is no direct transition to obtain more detailed information. The MSPD questions, on the other hand, are kept general in a way that the user decides to which level of detail they should be answered. The user can keep the answers on an overview level, but might also deepen to a more detailed level. Both TSPD and SLCM Matrix are tools that are easy to use without any deep knowledge, more effort is then needed for the Prioritization Matrix in the MSPD.

Concerning criterion number four, ‘trigger thinking’, the TSPD is the tool that promotes out-of-the-box thinking the most. The participants of the criteria workshop stated that the TSPD tool could be good for an overview as it triggers thinking. Yet, the tool in itself, with no sustainability expert to assist in using it as intended, only gives limited guidance for coming up with new ideas. The MSPD, on the other hand, provides more guidance with the questions that the user is exposed to. It, in fact, focuses on design aspects of a product and would be in line with the strategic goal “Innovate Green” (see Introduction, section 1.3). In addition to that, the MSPD has shown an ability to trigger creative thinking (Hallstedt 2008). The included questions are formulated in a very open manner and thereby provide room for new ideas and broader thinking. Overall, completely new out-of-the-box thinking, as the TSPD is likely to initiate, might take things one step too far at this point of time for Roxtec, whereas the MSPD better connects to the state Roxtec is currently in, namely in initial stages of introducing sustainability aspects into product development. With the MSPD, as a first step, Roxtec can focus on improving their already existing products in
regards to sustainability. The SLCM Matrix should be discarded from the selection in this regard, as it on its own is rather an evaluation tool and would not be of much help for Roxtec in developing new ideas for more sustainable products.

Ultimately, its flexibility, its possibility to prioritize according to business aspects and its potential to guide innovative thinking put the MSPD in the lead compared to the other two tools. Therefore, the MSPD is the selected tool for this study. It should be stated again at this point that the MSPD is only the tool that Roxtec would use to start the sustainability integration into its PDP. As described in the previous section, the three strategic tools for SPD complement rather than substitute each other. Integration of further tools, if required, might therefore be subject for further projects. Recommendations for further tools are addressed in the discussion section (see section 4.3) of this thesis.

Even though the MSPD fits best, we felt that it required some additional adaptations. Firstly, Byggeth and colleagues (2007, 9) mention that “[t]he MSPD could also be further adapted for implementation at the companies” and even points out some ideas for improvement. Secondly, MSPD is weakly represented in some of our selection criteria and there is room for improvement to fit the criteria better. Thirdly, we were limited in the amount of time to integrate the tool into the PDP with the organization, so we had to ensure that it would be concise and directly applicable to the organization.

Adapting the questions

We recognized that in regards to the content, the questions in the B-step are almost the same as those in the C-step. They mainly differ in their time perspective, i.e. B-step questions are present-oriented and C-step questions are future-oriented, or as Byggeth categorizes them “inventory-impact questions” and “improvement questions” (Byggeth et al. 2007, 4) respectively. For example, a B-step question would be ‘Is the product dissipative?’ and the corresponding C-step question is ‘What are the possible product concepts that are not leading to a dissipative use of the product and still satisfying the selected need?’. As it was a major criterion of Roxtec to start with a strategic tool for SPD that triggers thinking and supports them in finding innovations, we decided that the future oriented questions would rather suit this purpose. Furthermore, by focusing on the C-step questions we were able to cut down the number of questions by half,
i.e. from approximately eighty to forty questions. In addition we left out the PD questions of the MSPD because the organization has been around for a while and they have already formulated the needs and functions of its products and do not need to revisit these questions every time they go through the PDP. Byggeth herself mentions that the PD questions are intended for companies that do not have a specific PDP model defined (Byggeth et al. 2007, 4).

Since at this point the questions in the MSPD were worded in Swedish with partial translation into English, we had to reword and complete the translation into English. At the same time we took into consideration the fact that during first test runs of the MSPD a manufacturing company stated that “more product-specific hands-on guidance for their product category would have facilitated the use of the MSPD” (Byggeth et al. 2007, 8). Byggeth also confirms this later in her paper as an area for potential improvement (Byggeth et al. 2007, 9). Consequently, we rephrased and discarded some further C-step questions from the SPA modules. An example of a question that was taken out would be: ‘How can the product be designed to achieve a timeless and classic design so that the product does not need to be discarded because of outdated fashion?’ Fashion is not an aspect that Roxtec’s customers are concerned with, and thus, this question is not applicable to this organization. An example of a question that was rephrased would be ‘How can the product be designed to achieve an optimal lifespan?’ Since Roxtec has a wide range of products that are designed for different functions and meant for different life spans, the question was rephrased to ‘How can the product be designed to adapt the overall product quality so that it fits the lifespan?’

In addition, we found that not all questions were self-explaining, so we supplemented each question with a short guiding statement. For example to facilitate the understanding of the question ‘How can the product be designed to include materials that are part of natural cycles?’ a statement follows ‘Choose metals commonly found in nature, readily biodegradable chemicals or renewable materials’, thus providing the user with a better comprehension of what the question is addressing.

Adapting the structure

Furthermore, we wanted to stress the life-cycle perspective of the MSPD. As mentioned earlier, life-cycle perspective is a basis for a full sustainability perspective in product development. On top of that, it was
stressed by Roxtec to select a tool that encompasses a life-cycle perspective. Byggeth states that “Together the questions in these [SPA] modules cover the product life-cycle” (Byggeth et al. 2007, 4). Yet in MSPD, it is not immediately obvious which life-cycle stage a question refers to. In order to increase this visibility for the organization we decided to regroup the SPA modules according to life-cycle stages. For this we divided the product-life cycle into five distinct phases, namely upper supply chain (including resource extraction), production, distribution, use and end of life and allocated the questions to the appropriate life-cycle stages. An overview of all the questions after adaptation can be found in Appendix C.

Finally, we felt compelled by the fact that all participants in the criteria workshop at Roxtec mentioned that the chosen tool should clearly show the added value from a business perspective of each proposed sustainability aspect. The Prioritization Matrix of MSPD takes return on investment into consideration, yet we decided that for each solution that might be proposed for a specific question a statement about the required costs and efforts to implement that solution and the added value for the organization should be indicated directly. By this we stress a closer connection between the sustainability aspect addressed in the question and the added value for Roxtec. Last but not least, this data can later be used in the Prioritization Matrix.

The final adapted MSPD tool was presented to the organization in the structure illustrated in Figure 3.10: Structure of Adapted MSPD Tool.

The questions are organized by life cycle stages and the applicable SPs are indicated for each question. Furthermore, space is provided for the answer and information regarding additional costs and/or resources and added value.

<table>
<thead>
<tr>
<th>Life-cycle stage</th>
<th>Question</th>
<th>Sustainability Principles</th>
<th>Answer</th>
<th>Additional cost/resources</th>
<th>Added Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper supply chain</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 3.10: Structure of Adapted MSPD Tool.*
3.4 Step 4: Integration of the Selected and Adapted Strategic Tool for Sustainable Product Development into the Current Product Development Process

Tool integration workshop

The tool integration workshop was initiated with a short introductory presentation in which we discussed the four SPs and introduced the participants to the adapted MSPD tool. The relationship between each question of the MSPD tool and the SPs was mentioned. This introduction was kept very brief, since a general introduction of the FSSD was provided in an earlier phase (see section 1.3). The participants of the workshop included a research and development director, a project manager, a material specialist, two design engineers, a customer service manager, an environmental manager and a test and certificates manager. All participants were present for the majority of the workshop and actively contributed to the results.

Where to place the questions

After the participants had discussed a few questions and as the tool integration workshop progressed, they started discussing where in general in the PDP the questions should fit. They decided that questions about design should be raised no later than the Pre Study phase and if possible even earlier in the Business Opportunity Specification (BOS) phase. Asking questions on ‘how can the product be designed…’ in a later phase would bring the case that it would not be possible to change the design anymore or it would become increasingly costly and technically difficult. In the Pre Study phase, on the other hand, only a draft of the design is created which gives space for changing the design if needed.

With this in mind, most of the design related questions were placed in the Pre Study phase. The organization included one new question in the BOS phase about defining the life-span of the product in order to be able to answer other sustainability related questions in the Pre Study phase. Furthermore, the participants decided to include ‘How can the product be designed to include materials that are part of natural cycles?’ and ‘How can the product be designed so that no or less materials are required during the
product use (incl. installation) while still fulfilling the product function?’ as overview questions in the concept formulation section of the PDP. They discussed that these two questions could be explored at high level during this phase. The answers to those questions could be brief and not too precise, yet they ensure that innovative thinking towards more sustainable products is initiated at this early stage of the PDP. These two questions are also repeated in the Pre Study phase and the answers to them could be expanded upon at this stage.

Questions related to production operations were not dealt with within the scope of the mapped PDP as representatives from the organization pointed out during the workshop that they did not fit into the mapped PDP. Instead those questions better suit the daily production management and will be kept by the environmental manager. Similarly, supplier related questions are not dealt with in every single PDP project. Therefore, the questions were not implemented in the mapped PDP, instead those questions would be implemented in the strategic procurement department. An interview was conducted with the supply chain manager to discuss this issue. It was confirmed that those questions should be dealt with separately from the PDP.

A checklist of questions

During the grouping of the questions a discussion arose among the participants of how to best make sure that they will use the questions in their work. Since there are already different checklists in use in the current PDP - mainly connected to the BOS and PS documents - the organization thought it would be good to use the MSPD questions as a checklist. The participants decided to also keep the questions that require a long-term perspective in this checklist in order not to forget about them. It would be the responsibility of the designer to bring up the questions that need further analysis. There would be a check box called ‘more investigation required’ which would be selected if more comprehensive analysis is required. This way they would use all the questions in the beginning and get a feeling which questions need to be dealt with in the longer term and which can be dealt with in a short timeframe.

In addition, as described in Step 4 (see section 3.4) each question would be assigned an answer box for possible solution, additional cost and/or resources required when implementing the solution and added value for the organization through the solution. All these boxes would be used in the new
checklist. Finally, the participants requested that the connection of each question to the four SPs be shown in the checklist with a brief description of the four SPs as an introduction piece to the checklist. The following figure illustrates the structure of the checklist and provides an example question and the corresponding SPs involved (for the complete checklist see Appendix D).

<table>
<thead>
<tr>
<th>Question</th>
<th>Sustainability Principles</th>
<th>Answer</th>
<th>Additional Cost/Resources</th>
<th>Added Value</th>
<th>More Investigation Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Supply Chain</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>X</td>
</tr>
</tbody>
</table>

1.2. How can the product be designed to include materials that are part of natural cycles? Choose metals commonly found in nature, readily biodegradable chemicals or renewable materials.

Figure 3.11: Illustration of MSPD Checklist Structure.

The different nature of the questions

More in general, while the company representatives were grouping the questions and trying to integrate them into different PDP stages, they recognized that most of the questions would require more investigation and rather be dealt with in long-term projects before they would be able to come up with answers and proposals to these questions. In order to answer this kind of questions it might be necessary to use other tools that include deeper analyses such as conducting a full Life Cycle Assessment (LCA) or a comprehensive analysis with the Finite Element Method (FEM). These analyses could then be the input to how the organization could, for example, deal with a particular material or production method in the future. Moreover, participants found that answering these questions would require input from entities in the organization external to the current PDP. Yet, there is not enough time to investigate these more subtle questions for every single product development project that is handled in the current PDP. The current and mapped PDP deals with projects that have a rather short-term perspective. In this process questions should be raised to make the designer think of details such as the shape of the product to enable labeling, reduce weight, facilitate transport or use fewer materials to facilitate recycling. Even though that was not the purpose of the tool integration workshop and we tried to keep the participants on track to integrate the tool into the PDP, the questions created a good discussion and got the participants thinking regarding possible design solutions.
Prioritizing proposals

An additional interview was conducted with a product designer and project manager to discuss how the Prioritization Matrix could be used in the PDP and where it would fit. From the discussion it was concluded that it would be best, at this point of time, to include the Prioritization Matrix in the Risk Analysis section of the PDP. Yet, the interviewees expressed the need to try the process several times before the best placement for this component of the tool can be identified. It is likely that a stage earlier to the Risk Analysis would be more appropriate to ensure that there are still more degrees of freedom to change the design. Furthermore, it was stated in the discussion that the matrix would need to be extended to add other aspects of the product design and not be limited to sustainability related and business related criteria. An example of how the Prioritization Matrix could look like in the future is presented in the figure below.

<table>
<thead>
<tr>
<th>Prioritisation Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Proposal 1</td>
</tr>
<tr>
<td>Proposal 2</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>

Figure 3.12: Prioritization Matrix.
Summarizing, the following figure shows the results of the integration process:

![Diagram showing the integration process]

**Figure 3.13: Inclusion of Sustainability Aspects in Mapped PDP.**

### 3.5 Step 5: Test Case of the New Product Development Process in the Organization

In our test case we focused on a product development case around a new wedge and the associated stayplates.\(^4\) Concerning the stage of this test case in the current PDP, the Pre Study phase had just been completed, prototypes had been built and first tests had been scheduled for the coming weeks. In order to apply the new PDP a test run of the new PDP was conducted with the product designer. During the test case the product designer went through the checklist and answered the questions to the

\(^4\) For a more detailed explanation of the full sealing solution see section 1.4.
selected reference product. We, as observers, documented the results and the impact of the new PDP on the development of the new product.

**Difficulty to come up with new proposals**

When going through the checklist with the designer, we generally observed that he had difficulties to readily provide answers or solutions to the questions. For questions such as ‘How can the product be designed to include materials that are part of natural cycles?’, the designer said that he could not provide an answer as he did not have enough knowledge and information about what those materials and their capabilities are. The same applied, for example, for foreign and persistent substances or recyclable materials. Later he stated that when designing a product, he most often relies on materials that he is familiar with or that are commonly used in the industry.

Repeatedly the product designer pointed out that there is a need for further education in sustainability in order to be able to answer the questions. “The checklist”, he said, “provides direction, but does not help to give the concrete answers needed.” Those concrete answers, however, are necessary in order to include them into the current PDP. The designer indicated that further research was required for almost all of the questions. Finally he emphasized that first a list of materials is needed that indicates the materials’ corresponding impact on sustainability, in order to be able to begin developing more sustainable products: “Most of it is to choose the right material.”

**Functional and economic aspects in line with sustainability aspects**

Some sustainability aspects were already included in the design, yet they were not taken into consideration due to sustainability reasons, but due to reasons of cost reduction or of functional requirements. One example of the former was in regards to the question (2.1.): ‘How can the product be designed so that material consumption and energy consumption in production be reduced through more efficient production processes? Design for higher efficiency of material and energy consumption.’ At first the stayplates were supposed to be produced with small wings on the outside. After having ensured that they are not necessary due to production requirements, it was decided to leave them out in order to reduce material and, therefore, costs. Using less material and still achieving the same outcome is, however, also positive from a sustainability perspective. One
example in which functional requirements coincided with sustainability aspects was detected in the question (4.7.): ‘How can the product be designed to facilitate maintenance of the product? Design for easy maintenance.’ As it is very common to feed additional cables through the solution over the lifetime of the product, the parts have to be designed so that it is easy to replace some modules in the frame. In our case the designer particularly added two handles to the wedge so that it is easier for the user to take the wedge out in order to access the modules.

**Functional and economic aspects in conflict with sustainability aspects**

Throughout the test case, the designer had difficulty to come up with new ideas of how to make the product design more sustainable based on his current knowledge. Moreover, he seemed trapped within the limitations given by the fact that the product is part of an already existing product range or family. There were some ideas, but they were immediately dismissed by the designer as they were in conflict with functional and economic requirements as of today. For example, the designer mentioned that two different materials could be replaced by only one material that fits the requirements of both. Yet, he instantly pointed at the fact that this material is much more expensive than the others which are included in the current design. Furthermore, he mentioned that this material could not be recycled, whereas one of the others could. Moreover, the new material could not replace all of the other materials, as it would not fulfill the functional requirement that one of the other materials fulfills.

These considerations of evaluating sustainability aspects versus technical and economical aspects should be covered when completing the Prioritization Matrix. As the designer, however, had already dismissed these ideas when going through the checklist, there was no need to evaluate these questions against the prioritization parameters in this case.

**3.6 Step 6: Evaluation of the New Product Development Process**

The evaluation of the potential move of the new PDP towards sustainability was evaluated through discussion with experts including BTH strategic tools for SPD developers and project leaders and Roxtec representatives, including the research and development director, a product designer and the environmental manager. The evaluation was based on our defined purpose
for this study: ‘To assess whether a strategic move towards sustainability could be triggered by integrating a selected strategic tool for sustainable product development into the product development process of an SME’ (see Research Method, section 2.1). Thus, the following evaluation is structured to address this ‘strategic move towards sustainability’.

**Strategic**

The checklist can be considered ‘strategic’ as it is flexible to adaptations and changes, as necessary. Most interviewees agreed that changes and revisions to the questions would be needed, yet they would be easy to implement due to the flexibility of the tool. These changes can strengthen the applicability of the questions to the organization and increase the sense of ownership of the questions by the representatives of the organization. Some improvement suggestions from the interviews included increasing the consistency of the questions over all life-cycle stages and the columns in the checklist, especially the columns ‘additional costs/resources’ and ‘added value’ to make sure they are directly comparable. As well columns could be adjusted to provide an option for input of possible reduction of costs, as opposed to just additional costs, as well as, additional columns for prioritization.

Furthermore, the questions in the checklist do not prescribe a specific solution, but are open-ended and provide a flexible platform for the user to reflect on and consider different solutions, which also promotes innovation. The interviewees stated that the questions encourage new ideas with no limitations, so there are no restrictions on the timeframe or the complexity of the ideas. Yet, at the same time, an expert pointed out that some questions rather refer to gradual improvements (such as minimize, reduce, etc.) and do not fully open up. Therefore, some changes to the questions may be necessary to ensure they are entirely based on a backcasting and not on a forecasting perspective.

To expand on this flexible platform, it would be beneficial to develop a database to save the ideas that come up in the checklist and make sure that they do not get lost once the checklist and project are completed. If the database were set up, it would facilitate building up on different ideas and provide stepping stones to arrive at more sustainable product designs.

In terms of the process, experts thought it was strategic to have overview questions in the beginning of the process and have the questions spread out
throughout the whole PDP. However, in the developed PDP most of the questions still ended up in one phase and the structure and flow of the questions may not be immediately apparent. To build on that in the PDP, the stakeholders could be mapped out in the beginning of the process and an overview tool, such as the TSPD, could be implemented to strengthen the strategic approach of the new process.

**Move**

To ensure the developed process initiates a ‘move’, most interviewees mentioned that a next step that involves going through the new process in its entirety is necessary. Several iterations of the process are needed and the process should be used continuously so it becomes natural to the organization and not a barrier. In addition, review of the questions between the iterations would further support this link.

Roxtec representatives indicated that an initiative action is required from the management in order to make sure that the checklist is implemented and further steps are taken. The fact that the product development team was actively involved in the co-creation of the process is already a potential move. It was also mentioned that a meeting with the management was set up in the days following the evaluation interviews to discuss the implementation of the new process, which provides evidence of the potential initial move that has been triggered.

As seen in the test case, some sustainability aspects are already incorporated in product designs, but not due to sustainability reasons. Experts said that the checklist would make this reasoning visible so conscious actions could be taken. Many of these actions are more for the future and the process to answer the questions in the checklist and develop the corresponding solutions will likely take years. Therefore, the move may not be obviously apparent at this early stage, but the results show indication of an initial step.

**Towards**

‘Towards’ is regarded as providing guidance in the right direction. The interviewees thought that the adapted MSPD is a good guidance tool and leads to a new mindset that was not considered in the organization before. With the questions in mind new product ideas can pop up, as they make the user think differently and can act as a guide to lead in the right direction.
In terms of the structure of the checklist, all experts thought that the supporting statement to the questions are helpful and provide guidance to ensure that the user does not get stuck on trying to understand what is meant by the questions. Finally, the questions overall provide a direction to steer towards for developing new product ideas.

Sustainability

The description of the SPs in the checklist provides a definition of ‘sustainability’ and each question is linked to the SPs to indicate which principles are addressed. Both Roxtec and BTH representatives believed that it is an asset to include the SPs in the checklist. The interviewees indicated that the SPs connect the questions to “the earth” and provide a direction of thought.

Overall, the interviews with BTH and Roxtec representatives showed that the new process is a good start for a strategic move towards sustainability and, thus, supported the success of this thesis. The process helps structure, provides guidance, triggers new thinking and is very flexible. It is a stepping stone in a long journey of many more steps in the new direction.

Evaluation by the researchers

One could argue that no changes have been performed to the product in the test case and, therefore, there is no strategic move towards sustainability. The testing is the real exam of whether it is feasible to bring theory and practice together in the pursuit of practical solutions, i.e. to use the tool in the most common product development projects carried out by the organization. It has to be understood that a majority of the development projects are related to changes, extensions or additions of the existing product portfolio. This provides limitations in order to take considerable steps in new directions. There is a considerable challenge in changing an existing product in an existing product family by performing just one trial. Yet, the test case provides clear signs that the new PDP shall be seen as an initial – however small – step towards sustainability, and can be more successfully used for the development of totally new products and product families. Raising sustainability-related questions could indeed be regarded as an initial step towards sustainability in itself, since it creates awareness and makes the designer actively incorporate sustainability aspects into design decisions. This step is insofar strategic as the organization can now build upon it and as a next step investigate more into the questions that
were marked accordingly, for example the questions related to the material. If projects are initiated to investigate those questions, they could become stepping stones to developing more sustainable products. In this way, trade-offs between different aspects, as discovered in the test case, are now made visible which is the base to layout the strategic path to more sustainable products.
4 DISCUSSION

4.1 Research Question

To discuss the results of this thesis, this section is structured to address the research question developed in the beginning of this study (see Aim and Scope, section 1.3):

How can a selected strategic tool for sustainable product development be adapted and integrated into the product development process of an SME in the sealing industry?

In the following sections, the research question is divided into six components to address all aspects of the thesis as follows:

- ‘How can…’: addresses the methodology used in this project;
- ‘… a selected strategic tool for sustainable product development…’: discusses additional tools to the selected tool that could be integrated into the PDP;
- ‘… be adapted…’: reflects on the adaption of the selected tool;
- ‘… and integrated…’: discusses the integration of the selected tool;
- ‘… into the product development process…’: discusses the current PDP in the organization and provides suggestions for its adaptation;
- ‘… of an SME in the sealing industry? ’: reflects on the case study application of a strategic tool for SPD to the PDP of an organization.

4.2 How can...

The working method used for collaborating with the organization, as described in section 2.2, served the purpose of the thesis very effectively. The use of participatory action methods engaged the organization in the development of all aspects of the thesis and the outcome was truly a co-creative process. The organization was actively involved and this increases the likelihood that the outcome of this study will be further implemented beyond this thesis work. The process is easy to follow and adapt, as necessary, for implementation to organizations within different fields and
of different sizes. The use of workshops and interviews can be easily catered to fit the needs and requirements of the organization in question.

It should however be mentioned at this point that Participatory Action Research is often criticized due to its subjective and influential nature (Reason and Bradbury 2001). Concerning the validity of our findings, we backed up the results that we found through interactive workshops with follow-up interviews (see sections 2.3.1 and 2.3.4).

4.3 ... a selected strategic tool for sustainable product development...

Although the MSPD tool was the selected tool that fitted best for the purpose of this thesis, there is room for further integration with additional tools.

As mentioned in the evaluation step (see section 3.6), integrating an overview tool in the beginning of the PDP would be an asset. When presented with the TSPD tool, Roxtec representatives were quite fond of it as an overview tool (see section 3.3). They believed that it provides a useful high-level overview, triggers out-of-the-box thinking and would be easy to communicate within the organization. The TSPD or a similar tool can also support the few high-level sustainability related questions that were included in the early phase of the PDP (see section 3.4).

For further investigation into the checklist questions (Appendix D), especially the ones dealing with new materials and production methods, various more comprehensive tools could be useful. As mentioned in the introduction (see section 1.2), the list of available tools is extensive and the tool that best fits the given circumstances should be chosen.

4.4 ... be adapted...

The MSPD tool was adapted quite rigorously to fit the organization. As the tool was originally in Swedish and the English translation was quite rough, a considerable amount of rephrasing had to take place (see section 3.3). During the rephrasing, we tried to make the questions as clear and easy to understand as possible, but as it is the first version of our adapted MSPD tool, we believe that there is room for improvement to further clarify the questions. In addition, as proposed by the experts during the evaluation
phase of our research (see section 3.6), the questions should be further reviewed to ensure applicability and a natural fit to the process.

Another aspect of phrasing the questions was the fact that we made sure that all questions began with the statement ‘How can the product be designed…’ (see section 3.3). We included this statement to ensure that all questions relate to the product development as opposed to the production or use phases of the product life-cycle. However, during the tool integration workshop, this wording may after all have shifted the participants into a specific direction. Concerning the validity, one might say that it appeared that they felt compelled to put the questions in an earlier phase of the PDP and they did not think the questions fit in later phases. This also could have happened since they understood that early in the process the design freedom is the greatest. So this phrasing of the questions may have served the purpose more rather than creating a biased result.

4.5 ... and integrated...

During the tool integration workshop, the questions created a good discussion and got the participants thinking regarding possible design solutions (see section 3.4). Even though that was not the purpose of the workshop and we tried to keep them on track to integrate the tool into the PDP, the discussion regarding possible design solutions shows that the adapted MSPD tool promotes innovative thinking.

The test case that was conducted provided a very limited simulation of the integration of the tool into the PDP. Firstly, the product that was evaluated for the test case was already in a phase following the Pre Study and, thus, further along in the PDP than where the checklist should be implemented. Regarding validity, one might say that this circumstance limited the amount of changes that could have been considered for the design and, consequently, limited the extent of exploration into the questions of the tool. Secondly, due to the nature of the answers obtained in the checklist, there was no practical benefit in simulating the prioritization component of the tool in this case.

Even though the prioritization component of the tool was not tested, for the next iteration of the process, it would be beneficial to include an introduction of the prioritization aspects in the early stage of the PDP. This introduction could include answers to questions such as ‘How
environmentally aware is the customer?’ and ‘Would the customer be willing to pay a higher price for more sustainable products?’ This would ensure that the product development group is aware of sustainability aspects already in the early stages of the process. Moreover, some overview questions were already put into the concept formulation phase (see section 3.4). One might argue if this is the right place from a sustainability point of view. This leads into a general question of whether a sustainability expert should have directed the participants more in placing the questions to ensure that the new product development process really aims at developing more sustainable products. We believe that as the MSPD is intended for the questions to be spread throughout the whole PDP, company representatives know best who should answer which question when.

As mentioned by the experts in the evaluation, several iterations of a complete simulation need to take place to observe the full impact of the new process (see section 3.6). Revisions of the process can take place between iterations to provide a more natural fit of the tool in the process and increase efficiency in its integration.

4.6 ... into the product development process...

As seen in results, the current PDP within the organization is intended to deal with short-term product development and new product design (see section 3.4). Most of the time the current PDP is triggered by specific customer requests or specific identified needs in the market. Moreover, most of the products already belong to a specific product range or family. Hardly any of those initiatives are currently triggered through the consideration of sustainability.

From the tool integration workshop and test case results it was clear that some of the questions in the MSPD checklist are too comprehensive and could not be answered for every single product development project. These questions would require more sustainability related education and research within the organization in order to be able to develop applicable answers or solutions to them. Being a method based on questions, the MSPD itself does not provide the organization with answers.

A possible structure for exploring these questions that require long-term investigation could be for the designer to bring them to the project management for the potential creation of a new follow-up project. Going
through the current PDP, however, is not suitable for long-term investigation of those questions. An extension of the PDP or a new complementary process, both with focus on long-term solutions and bridged with other organizational processes, could be two options.

It would be beneficial to use as much of the existing PDP as possible so that there is close co-operation between the different departments. As seen in the results, currently, there are no – or only few in a later stage – representatives from production, supply chain, packaging, delivery, etc. in the project team for PDP. To deal with questions regarding production capabilities and suppliers, personnel are contacted from outside of the team. This structure tends to separate the involved parties and to limit the possibilities to optimize the design. By incorporating the PDP bridged with other organizational processes, other departments within the organization might become more involved in the development of new products and thereby also able to provide the necessary input to make the products more sustainable (see Figure 4.1). As mentioned in the introduction the common understanding of sustainability through the four SPs facilitates the necessary communication across functions in the organization (see section 1.3). The resulting extended PDP would have a long-term perspective and involve a more comprehensive process to arrive at more sustainable products. Whether the extended PDP is integrated with other organizational processes or becomes a separate process has yet to be decided.
Introducing a new department dealing only with long-term, comprehensive questions might be an asset in this regard. This team would take upon research on long term questions raised in the MSPD concerning, for example, the use of new materials or new production methods that are far reached for typical PDP projects. This department dealing with PDP bridged with other organizational processes would involve representatives from various company departments to ensure input from throughout the company.

4.7 … of an SME in the sealing industry.

The practical application of the adapted MSPD tool to Roxtec, an SME in the sealing industry, is a contribution to the research conducted at BTH. Information was gained on the value and practicality that the tool can bring to the organization and what is necessary to further optimize this tool. The case study provides evidence of gained insights that the tool can provide to strategically move an organization towards sustainability. It is also a practical case study that could be used for the ‘Sustainable Product Innovation Research Initiative’ (SPIRIT) of the Real Change program.
5 CONCLUSION & FURTHER RESEARCH

5.1 An Effective Method to Work with Organizations

Our participatory approach of selecting, adapting and integrating a strategic tool for SPD led to high engagement among participants from the organization which in turn increases the likelihood that the outcome of this study will be further implemented beyond this thesis work. This collaborative and truly co-creative working method can be seen as an effective process for integrating tools for SPD into PDP when working with organizations.

5.2 MSPD Questions as a Checklist for the Product Designer

In our case we selected and furthermore adapted the MSPD as the strategic tool for SPD to be integrated based on requirements provided by the organization. The integration led to most of the questions being handled by the product designer in the form of a checklist in the Pre Study phase. Further investigation is required in terms of the reasoning to why most of the questions ended-up in one specific spot in the PDP although the MSPD claims that the questions can be used throughout the whole PDP. The Prioritization Matrix was placed in a later phase in which risk analysis is conducted.

5.3 A Long-term, Organizational-wide Effort for Answering the Questions

Throughout the case the MSPD has proven to trigger thinking regarding sustainability in product development. However, it is difficult to come up with answers to the questions on the spot. In order to answer most of the questions further investigations are required. The practical application of the MSPD has furthermore shown that in order to answer most of the MSPD questions for Roxtec, further education in sustainability is required. Long-term projects with input from all entities within Roxtec need to be created to tackle several of the questions. The current PDP was not designed to deal with these projects as it is designed to rather fast respond
to customer requests and market needs through adaption of products from already existing product ranges or families.

Concerning the MSPD the findings raise the question of what influence the actual PDP of an organization has on the suitability of the MSPD. Further research may be necessary on how the nature of the different questions in the MSPD determines how a PDP should be designed, in terms of, for example, timeframe and organization-wide cooperation, in order to deal with the questions. This would also be in line with the fact that the questions need to be further investigated concerning their consistency.

### 5.4 An Initial Step to Further Move towards Sustainability

In terms of sustainability, awareness was raised and product development decisions in its regard can now be taken consciously. The MSPD can serve as a flexible platform as the tool can be further adapted and allows other tools to supplement it. In the expert talks it was confirmed that raising sustainability related questions could be seen as an initial – and also initiating – step to integrate sustainability aspects into product development and thus strategically move Roxtec further on a long journey towards sustainability. Nevertheless, it was concluded that the next step would be running the new PDP several times in order to gain more information on how well it works and where it needs adaptations.

### 5.5 Closing Remarks

This thesis represents a further step for Roxtec to fulfill its roadmap towards sustainability outlined through the seven strategic goals that were developed in the previous project and thus also represents a small step to face the sustainability challenge of our society.
References


Ny, H., J.P. MacDonald, G. Broman and K.-H. Robèrt. 2009. Sustainability constraints as system boundaries: Introductory steps toward strategic life-


Appendices

Appendix A: Mapped PDP.

Legend to Event Driven Process Chain
Roxtec’s Current Product Development Process, Part 1
### Appendix B: Tool Evaluation using the Defined Criteria

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Fast, easy and flexible</strong></td>
<td>The questions are intuitive and therefore easy to implement, use and maintain. More effort is expected for the Prioritization Matrix. The time consuming aspect of the tool is rather the process of finding more sustainable solutions.</td>
<td>TSPD is a quick overview tool. It is easy and simple to use.</td>
<td>SLCM matrix is a quick overview tool. It is easy and simple to use.</td>
</tr>
<tr>
<td><strong>Part of the already existing process</strong></td>
<td>MSPD is very flexible with the SPA modules and questions. The organization can decide where each part goes and thereby make it natural to its product development process. This was confirmed in previous tests with other organizations. (Byggeth et al. 2007, 8)</td>
<td>TSPD seems pretty inert, i.e. it is hard to decompose it into different parts and then align them with the existing product development process. It could be a standalone early exercise that the design team goes through and then keep the template as a reference document that is refined as the development project moves on. It is meant to be used in the very early stages of the product development process. (Ny et al. 2008, 605)</td>
<td>The SLCM matrix is used to provide “an overview of the whole system through the lens of the four sustainability principles.” (Ny et al. 2006, 71). It can be used in an early stage of the product development process, potentially as an extension of the TSPD, but is not of much use for other stages.</td>
</tr>
</tbody>
</table>

67
| **Business perspective**  
(***mainly economic prioritization support***) | The business perspective is not directly incorporated into the SPA modules, but rather included in the Prioritization Matrix that involves evaluation based on return on investment. (Byggeth et al. 2007, 6) | Economic prioritization is intentionally not explicitly mentioned in TSPD, yet the first template is about current and future market desires and needs which builds the base for product demand. (Byggeth et al. 2007, 6) | SLCM matrix does not in itself incorporate a business perspective. |
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<tbody>
<tr>
<td><strong>Trigger thinking</strong></td>
<td>The open format of particularly the C-step questions of the MSPD support awareness and creativity in finding new solutions. This was confirmed in previous tests with other organizations (Byggeth et al. 2007, 8).</td>
<td>“[T]he templates purpose is not to be prescriptive but to trigger creativity” (Ny et al. 2008, 606).</td>
<td>The SLCM matrix is used to provide “an overview of the whole system through the lens of the four sustainability principles.” (Ny et al. 2006, 71). This overview may encourage creative thinking.</td>
</tr>
<tr>
<td><strong>Ease of communicating results internally</strong></td>
<td>The Prioritization Matrix is meant to support internal communication, as it brings all information together. This was confirmed in previous tests with other organizations. (Byggeth et al. 2007, 8). At the same time, questions might be scattered throughout the product development process and thus this could hinder internal communication.</td>
<td>Internal communication of sustainability related aspects of a product between different departments and the management is mainly the purpose of TSPD. “The TSPD approach has, in the Matsushita case, been demonstrated to be a functional basis for dialogue about sustainability-related issues within the company and thereby for facilitating sustainability-related decision making later on.” (Ny et al. 2008, 619). This was backed up further by the Matsushita case (Ny et al. 2008, 620).</td>
<td>The simple format of the matrix and its use with different colours can provide a quick visual help to highlight the sustainability hotspots of the product in its full life cycle.</td>
</tr>
<tr>
<td><strong>Life-cycle perspective</strong></td>
<td>MPSD questions cover the product’s full life cycle (Byggeth et al. 2007, 4).</td>
<td>“Template II (Concept)... gives early indications of negative impacts on ecological and social systems that product concepts might cause throughout their life-cycle” (Ny et al. 2008, 609).</td>
<td>SLCM and the matrix evaluates “how a certain organization or product, throughout its life cycle, contributes to society’s violation of the SPs.” (Ny et al. 2006, 71)</td>
</tr>
<tr>
<td><strong>Valuation (against definition of sustainability)</strong></td>
<td>MSPD entails a Prioritization Matrix that helps prioritize between solution alternatives that favour different sustainability aspects (prioritization criterion “Right direction”). However, like the questions, the prioritization is also on a very general level (e.g. no comparison of global warming potential against eutrophication). (Byggeth et al. 2007, 6)</td>
<td>TSPD does not provide a prioritization of sustainability aspects for the product development process, but information from the TSPD can be used as input for later detailed prioritization (Ny et al. 2008, 606).</td>
<td>SLCM matrix provides a very high level valuation of each life cycle stage of the product against the SPs. Information from the matrix can be expended upon “to give more information on priorities”. (Ny et al. 2006, 71)</td>
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</table>
Appendix C: MSPD Questions

Primary Questions:

<table>
<thead>
<tr>
<th>Life Cycle Stage</th>
<th>Question</th>
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</thead>
<tbody>
<tr>
<td><strong>Supply: Material</strong></td>
<td>1.1. How can the product be designed to include materials that are part of natural cycles? Choose metals commonly found in nature, readily biodegradable chemicals or renewable materials.</td>
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<tr>
<td></td>
<td>1.2. How can the product be designed so that the quality of the material (e.g. alloy, additives, etc.) be adapted to match the required function and/or lifespan of the product? Choose or design materials for required function and lifespan.</td>
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<tr>
<td></td>
<td>1.3. How can the product be designed to reduce the amount of materials in the product while still fulfilling the product function? Reduce amount of materials in the product.</td>
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<td></td>
<td>1.4. How can the product be designed so that it does not include materials that involve major production of emissions throughout the supply chain processes? Choose materials that are produced with no or least emissions.</td>
</tr>
<tr>
<td></td>
<td>1.5. How can the product be designed to include materials that do not involve supply chain processes that damage or deplete nature? Choose materials that do not involve loss of biodiversity, reduction of long-term productive capacity, etc.</td>
</tr>
<tr>
<td></td>
<td>1.6. How can the product be designed to include recycled or reused materials or with a higher share of recycled or reused materials? Design for recycled or reused materials.</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td>2.1. How can the product be designed so that material consumption in production be reduced through more efficient production processes? Design for higher efficiency of material consumption.</td>
</tr>
</tbody>
</table>
2.2. How can the product be designed so that energy consumption in production be reduced through more efficient production processes?
Design for higher efficiency of energy consumption.

2.3. How can the product be designed so that the amount of foreign and persistent substances currently used in production be avoided or minimized?
Avoid harmful substances.

2.4. How can the product be designed so that waste be eliminated or minimized in the current production process?
Design to eliminate production of waste.

2.5. How can the product be designed so that emissions be eliminated or minimized in the current production process?
Design to eliminate production of emissions.

2.6. How can the product be designed so that current production processes eliminate or minimize damage or depletion of nature?
Design to ensure that processes do not involve loss of biodiversity, reduction of long-term productive capacity, etc.

2.7. How can the product be designed so that current production processes improve social environment in terms of air, noise, light, ergonomics, physical and mental work?
Design for improved social environment.

3.1. How can the product be designed for reduced weight in order to reduce energy consumption in the transport of the product?
Design for reduced weight.

3.2. How can the product be designed for efficient packaging?
Design efficient packaging.

4.1. How can the product be designed so that no or less energy are required during the product use (incl. installation) while still fulfilling the product function?
Design for less energy during use.

4.2. How can the product be designed so that no or less materials are required during the product use (incl. installation) while still fulfilling the product function?
| Design for less materials during use. | 4.3. How can the product be designed so that it does not spread to nature during use (incl. installation) (e.g. rust, wear, abrasion) while still fulfilling the product function? Design for no dissipation during use. |
| Design for meeting multiple needs. | 4.4. How can the product be designed so that multiple needs - in addition to the selected need - are satisfied? Design for no dissipation during use. |
| Design quality to match the lifespan. | 4.5. How can the product be designed to adapt the overall product quality so that it fits the lifespan? Design for meeting multiple needs. |
| Choose materials and chemicals that are part of natural cycles. | 4.6. How can the product be designed to avoid materials or chemicals required during use that cannot be incorporated into natural cycles? Design for quality to match the lifespan. |
| Design for increased efficiency through user education. | 4.7. How can the product be designed to increase efficiency of material consumption during use (including installation) by educating or informing the users? Design for no dissipation during use. |
| Design product for easy repair. | 4.8. How can the product be designed so that all product parts can be replaced or repaired easily? Design for meeting multiple needs. |
| Design for easy maintenance. | 4.9. How can the product be designed to facilitate maintenance of the product? Design for increased efficiency through user education. |

| Disposal | 5.1. How can the product be designed so that all materials in the product can be recycled? Choose recyclable materials. |
| Label materials for recycling. | 5.2. How can the product be designed to include material labeling to facilitate recycling? Design for no dissipation during use. |
| Design for few materials. | 5.3. How can the product be designed with less material types to facilitate recycling? Design for meeting multiple needs. |
| Design for easy disassembly and separation of materials. | 5.4. How can the product be designed so it is easy to disassemble and separate different materials? Design for quality to match the lifespan. |
| Design for reuse. | 5.5. How can the product be designed so that the reuse of the product can be increased? Design for no dissipation during use. |
### Additional Questions:

<table>
<thead>
<tr>
<th>Supply: Procurement</th>
<th>1a.1. From which suppliers that produce less or no waste can you buy the required materials? Choose suppliers with no or less waste.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1a.2. From which suppliers that produce less or no emissions can you buy the required materials? Choose suppliers with no or less emissions.</td>
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<tr>
<td></td>
<td>1a.3. From which suppliers that depend on no or less mined materials can you buy the required materials? Choose suppliers that use recycled or natural materials for the production of the material.</td>
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<tr>
<td></td>
<td>1a.4. From which suppliers can you purchase recycled or reused materials or with a higher share of recycled or reused materials? Choose suppliers of recycled or reused materials.</td>
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<tr>
<td></td>
<td>1a.5. From which suppliers that use renewable energy or avoid fossil fuels can you buy the required materials? Choose suppliers that use renewables.</td>
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<td></td>
<td>1a.6. From which local suppliers can you buy the materials? Choose local suppliers.</td>
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<td></td>
<td>1a.7. From which suppliers that have an environmental policy can you buy the required materials? Choose environmental conscious suppliers.</td>
</tr>
<tr>
<td></td>
<td>1a.8. From which suppliers that do not involve processes that damage or deplete nature can you buy the required materials? Choose suppliers that do not involve processes that result in loss of biodiversity, reduction of long-term productive capacity, etc.</td>
</tr>
<tr>
<td></td>
<td>1a.9. From which suppliers that support a fair allocation of resources can you buy the required materials? Choose suppliers that live up to an ethical code of conduct or have a fair trade policy.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Production (If the new product design)</th>
<th>2a.1. How can material consumption in production be reduced through more efficient production processes? Ensure higher efficiency of material consumption.</th>
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<tbody>
<tr>
<td></td>
<td>2a.2. How can energy consumption in production be reduced through more efficient production processes? Ensure higher efficiency of energy consumption.</td>
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<td></td>
<td>2a.3. How can the amount of foreign and persistent</td>
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<td>requires changes in the production equipment and/or processes...</td>
<td>substances be avoided or minimized?</td>
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<td>---------------------------------------------------------------</td>
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<tr>
<td></td>
<td>Avoid harmful substances.</td>
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<tr>
<td>2a.4. How can the additional waste be eliminated or minimized in the current production process?</td>
<td>Eliminate additional production of waste.</td>
</tr>
<tr>
<td>2a.5. How can the additional emissions be eliminated or minimized in the current production process?</td>
<td>Eliminate additional production of emissions.</td>
</tr>
<tr>
<td>2a.6. How can the additional production processes eliminate or minimize damage or depletion of nature?</td>
<td>Ensure that processes do not involve loss of biodiversity, reduction of long-term productive capacity, etc.</td>
</tr>
<tr>
<td>2a.7. How can the additional production processes improve social environment in terms of air, noise, light, ergonomics, physical and mental work?</td>
<td>Ensure improved social environment.</td>
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</table>
Appendix D: MSPD Checklist.

Method for Sustainable Product Development Checklist

The purpose of this checklist is to engage innovative thinking in order to develop more sustainable products and move the organization towards sustainability.

The checklist provides questions to address the full life cycle of the product. The “Upper Supply Chain” and “Production” phases address product ideas with new materials and new production methods. “Distribution”, “Use” and “End of Life” phases address all new product ideas.

The checklist is meant to be a guide to evaluate the business benefits that sustainability aspects could bring to the products and the company. Space is provided in the checklist to indicate the additional costs and/or resources and added value involved with each sustainability aspect.

The checklist is based on a sustainability definition comprised of four principles:

“In a sustainable society, nature is not subject to systematically increasing…

I (Sustainability Principle 1)...concentrations of substances extracted from Earth’s crust
[Substances from the earth’s crust include all substances extracted through mining and/or drilling. Some examples of these substances are metals such as iron, aluminum or cadmium. Whereas concentrations of iron and aluminum are abundant in nature, the concentration of cadmium is scarce (see table of concentrations attached)].

II (Sustainability Principle 2)...concentrations of substances produced by society
[Substances produced by society could include emissions and/or manmade chemicals related to the product and its production, such as CFCs or Wärmeträgersalz (see Volvo Grey List attached). Concentrations of all substances in nature vary strongly and their cycles need to be considered.]

III (Sustainability Principle 3)...degradation by physical means
[Degradation by physical is related to, for example, the abuse of productive land or the over-consumption of water required for production of the product.]

And, in that society

IV (Sustainability Principle 4)...people are not subject to conditions that systematically undermine their capacity to meet their needs”.
[Undermining people’s capacity to meet their needs means setting up barriers for people to meet their needs that could be caused by the product through, for example, unsafe working conditions and/or unfair trade.]

All questions in the checklist are formulated from the perspective of sustainability. The questions should support you in making your products more sustainable. Each question covers different sustainability principles as indicated in the table.

Attachments:

- Concentrations table.
- Volvo Grey List.
## Sustainable Product Development Checklist

For product designs with new materials and/or new production equipment and processes, please fill in all pages.

Otherwise, if existing materials and existing production are used, skip to page 3.

<table>
<thead>
<tr>
<th>Question</th>
<th>S</th>
<th>P</th>
<th>S</th>
<th>P</th>
<th>Answer</th>
<th>Additional Costs/Resources</th>
<th>Added Value</th>
<th>More Investigation required</th>
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<tbody>
<tr>
<td><strong>Upper Supply Chain</strong></td>
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<tr>
<td>1.1. How can the product be designed to include materials that are part of natural cycles?</td>
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<td>Choose metals commonly found in nature, readily biodegradable chemicals or renewable materials.</td>
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<td>1.2. How can the product be designed so that the quality of the material (e.g. alloy, additives, etc.) be adapted to match the required function and/or lifespan of the product?</td>
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<td>Choose or design materials for required function and lifespan.</td>
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<td>1.3. How can the product be designed to reduce the amount of different materials in the product while still fulfilling the product function?</td>
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<td>Choose materials that do not involve supply chain processes that damage or deplete nature?</td>
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<tr>
<td>1.4. How can the product be designed to include materials that do not involve supply chain processes that damage or deplete nature?</td>
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<tr>
<td>Choose materials that do not involve loss of biodiversity, reduction of long-term productive capacity, etc.</td>
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<tr>
<td>Question</td>
<td>S P 1</td>
<td>S P 2</td>
<td>S P 3</td>
<td>S P 4</td>
<td>Answer</td>
<td>Additional Costs/Resources</td>
<td>Added Value</td>
<td>More investigation required</td>
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<td>1.5.</td>
<td>X</td>
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<tr>
<td>How can the product be designed to include recycled or reused materials or with a higher share of recycled or reused materials? Design for recycled or reused materials.</td>
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<tr>
<td><strong>Production</strong></td>
<td>2.1.</td>
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<tr>
<td>How can the product be designed so that material consumption and energy consumption in production be reduced through more efficient production processes? Design for higher efficiency of material and energy consumption.</td>
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<td>2.2.</td>
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<tr>
<td>How can the product be designed so that the amount of foreign and persistent substances currently used in production be avoided or minimized? Avoid harmful substances.</td>
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<td>2.3.</td>
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<td>How can the product be designed so that emissions be eliminated or minimized in the current production process? Design to eliminate production of emissions.</td>
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<td>2.4.</td>
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<tr>
<td>How can the product be designed so that current production processes eliminate or minimize damage or depletion of nature? Design to ensure that processes do not involve loss of biodiversity, reduction of long-term productive capacity, etc.</td>
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<td>2.5.</td>
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<td>X</td>
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<tr>
<td>How can the product be designed so that current production processes improve social environment in terms of air, noise, light, ergonomics, physical and mental work? Design for improved social environment.</td>
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</tbody>
</table>
The following questions apply to all new product designs.

<table>
<thead>
<tr>
<th>Question</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>Answer</th>
<th>Additional Costs/Resources</th>
<th>Added Value</th>
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<tbody>
<tr>
<td><strong>Distribution</strong></td>
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<tr>
<td>3.1. How can the product be designed for reduced weight</td>
<td>X</td>
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<td>in order to reduce energy consumption in the transport of the product?</td>
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<td>Design for reduced weight.</td>
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<td>3.2. How can the product be designed for efficient packaging?</td>
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<td>Design efficient packaging.</td>
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<td><strong>Use</strong></td>
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<tr>
<td>4.1. How can the product be designed so that no or less</td>
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<td>X</td>
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<td>materials are required during the product use (incl.</td>
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<td>installation) while still fulfilling the product function?</td>
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<td>Design for less materials during use.</td>
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<td>4.2. How can the product be designed so that multiple</td>
<td>X</td>
<td>X</td>
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<td>needs - in addition to the selected need - are satisfied?</td>
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<td>Design for meeting multiple needs.</td>
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<tr>
<td>4.3. How can the product be designed to adapt the overall product</td>
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<td>quality so that it fits the lifespan?</td>
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<td>Design quality to match the lifespan.</td>
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<td>4.4. How can the product be designed to avoid materials or chemicals</td>
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<td>required during use that cannot be incorporated into natural cycles?</td>
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<td>Choose materials and chemicals that are part of natural cycles.</td>
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<tr>
<td>Question</td>
<td>SP 1</td>
<td>SP 2</td>
<td>SP 3</td>
<td>SP 4</td>
<td>Answer</td>
<td>Additional Costs/Resources</td>
<td>Added Value</td>
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<td><strong>4.5.</strong> How can the product be designed to increase efficiency of material consumption during use (including installation) by educating or informing the users? Design for increased efficiency through user education.</td>
<td>X</td>
<td>X</td>
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<tr>
<td><strong>4.6.</strong> How can the product be designed so that all product parts can be replaced or repaired easily? Design product for easy repair.</td>
<td>X</td>
<td>X</td>
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<td><strong>4.7.</strong> How can the product be designed to facilitate maintenance of the product? Design for easy maintenance.</td>
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<td>X</td>
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<td><strong>End of Life</strong></td>
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<tr>
<td><strong>5.1.</strong> How can the product be designed so that all materials in the product can be recycled? Choose recyclable materials.</td>
<td>X</td>
<td>X</td>
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<tr>
<td><strong>5.2.</strong> How can the product be designed to include material labeling to facilitate recycling? Label materials for recycling.</td>
<td>X</td>
<td>X</td>
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<td><strong>5.3.</strong> How can the product be designed with less material types to facilitate recycling? Design for few materials.</td>
<td>X</td>
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<tr>
<td><strong>5.4.</strong> How can the product be designed so it is easy to disassemble and separate different materials? Design for easy disassembly and separation of materials.</td>
<td>X</td>
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<tr>
<td><strong>5.5.</strong> How can the product be designed so that the reuse of the product can be increased? Design for reuse.</td>
<td>X</td>
<td>X</td>
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