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Identifying, collecting, and compiling sustainability information relevant to Norwegian manufacturing firms

Thesis for the degree of Philosophiae Doctor

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Preface

This doctoral thesis is the result of a PhD project carried out at the Department of Engineering Design and Materials, at the Norwegian University of Science and Technology (NTNU) in Trondheim. The PhD project was performed in the period of October 2008 till March 2012.

My main supervisors during the PhD project have been Knut Einar Aasland, Assistant Professor at the Department of Engineering Design and Materials, and Casper Boks, Professor at the Department of Product Design. In addition, Professor Sigurd Støren at the Department of Engineering Design and Materials made valuable contributions during the first years of the project.

The PhD project has been part of the Centre for Research-based Innovation – Norwegian Manufacturing Future (SFI Norman), and was funded by the Norwegian Research Council and participating firms. Throughout the PhD project five firms have participated in the PhD project, three of them being part of the SFI Norman project. Due to confidentiality and for competitive reasons, one of the case firms does not wish to be named. The other firms are Kongsberg Automotive (automotive supplier), Plastal (automotive supplier), Ekornes (furniture manufacturer) and Scandinavian Business Seating (furniture manufacturer).

The research project has given me a unique opportunity to learn about and make contributions to a field that I believe will become more and more important in the future, namely sustainability in the context of product development. My personal interest in the topic has evolved from 12 years of work experience in different industries, mainly with environmental and safety issues both in engineering and from a more operational viewpoint.

The results from this PhD project will hopefully be interesting to practitioners in firms working with product development as well as to research scientists within this field.

Kapp, March 2012

Silje Helene Aschehoug

Acknowledgements

A PhD project involves a lot of work, but above all, it could not have been carried out without the support and contribution from others. There are many people who have been important contributors and to whom I would like to express my gratitude.

First of all, I would like to thank my main supervisor Assistant Professor Knut Einar Aasland for his support, encouragement and practical guidance. I would also like to express my gratitude to co-supervisor Professor Casper Boks. He has given valuable specialist contribution to the research topic, to article writing but also by contributing with his network within the research community. Professor Sigurd Støren has also been important by discussing the larger questions of research and possible different directions in the early phases of the PhD work.

My PhD project is largely based on information and interviews from case studies. I would like to thank all the participating firms for their kind contributions; especially Hege Solerød, Øystein Lintvedt, Christian Lodgaard, Anders Ramstad, in addition to managers at the fifth case firm.

I would further like to thank the following:

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- Odd Myklebust, SINTEF Teknologi og Samfunn: for giving me the opportunity to start with the PhD project within the Norman project.
- Eirin Lodgaard, PhD colleague: for being a role model by starting her PhD work first. For discussing, helping, encouraging, supporting in every aspect during the PhD work.
- Colleagues at SINTEF Raufoss manufacturing.
- Marianne Falkenås, my childhood friend: for supporting me and believing in me.

To my mother Kari Prestmo Aschehoug and father Øyvind Aschehoug; I want to express my gratitude for your hospitality during my stays in Trondheim, for cooking excellent breakfasts and dinners, for being wonderful grandparents for my children when they travelled with me, and above all, for encouraging me in my work. I'm also very grateful to my mother for her English proof reading.

I would like to thank my sister Anne Kristin Aschehoug who always has had more faith in me than I have had myself, for enduring my frustrations, for good discussions, and for encouraging me during my work.

Finally, I would like to give special thanks to my husband Sverre Morken and my two daughters, Solveig and Sunniva for being there for me and for helping me maintain a good work - life balance during the PhD project. I could not have completed my PhD project without your loving support.

“It is a very sad thing that nowadays there is so little useless information”

Oscar Wilde

Reader's guidance

This doctorial thesis is written for practitioners within product development and design, scientists, and other personnel with knowledge or interest in sustainable product development and sustainability related issues. Extensive prior knowledge about this field is not required for reading this thesis as the basic concepts and constructs behind the research will be explained.

The thesis has IV parts, Part I: Main report, Part II: The sustainability information frameworks, Part III: Supplementary information and theory, and Part IV: Article collection

- Part I: The main report includes introduction and research questions, as well as a brief introduction to basic constructs and theory behind the presented research. The main report also includes a description of main findings based on the research.
- Part II: The sustainability information frameworks are presented here: both the early in-depth version with full author references, as well as the final version of the sustainability information framework. In addition, supplementary results from the case firms concerning sustainability information implementation are presented in this part.
- Part III: Supplementary information and theory necessary to understand the PhD work more in depth has been included in this part. Readers that are unfamiliar with the topics of sustainability, stakeholders, or information, may find more in-depth descriptions in this part. Moreover, an extensive introduction to research methodology is given in this part.
- Part IV: The five articles that have been developed as part of this research project have been included in this part. One article has been published in *Journal of Cleaner Production*, one has been accepted for publishing in *International Journal of Sustainable Engineering*, and one has recently been submitted to *Progress in Industrial Ecology, An International Journal*. In addition, two articles have been developed and presented as full paper presentations at international conferences.

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Part I: The main report

1 Introduction

Today, the tangible and intangible results of unsustainable consumption and production are increasingly becoming apparent to the public. Global warming, floods, hurricanes and other forms of extreme weather, water, air and ground pollution, uneven distribution of wealth and poverty, and extreme population growth are forcing firms to rethink how they deal with competitiveness and shareholder values. Whether firms should consider their social and environmental responsibility and the impact their activities have on stakeholders is no longer up for discussion (Epstein 2008). The question is rather how to integrate sustainability issues in day-to-day decisions, actions, and strategic priorities, like in product development and design.

Within the field of product development and design, the demands are ever increasing. Product development and design is faced with increased complexity, such as the challenges of new materials or technologies, designing entirely new products that the market has never seen (Cross 2008), or designing new products with radical new meanings (Verganti 2009). At the same time, the changing realties of an ever increasing pace of globalization results in increased competition and more dynamic markets (Ringen 2010). Future prospects indicate that the time span for product life cycles will decrease, as customers demand new products with higher quality and at an increasing pace (SFI-Norman 2008, Verganti 2009). This product consumption pattern is believed to be driven by better performance of products and new functionalities (Griese 2007). Resource consumption, however, cannot increase accordingly, which requires a different approach to product development and design.

One contribution from researchers to these substantial challenges has been in the development of new tools and methodologies for ecodesign and sustainable product development (Baumann et al. 2002, Hauschild et al. 2005, Karlsson and Luttropp 2006, Ilgin and Gupta 2009). Since up to 80% of environmental and social cost factors of a product are determined in product development and design (Charter and Tischner 2001, Maxwell and van der Vorst 2003), changes and improvements to the sustainability attributes of products can be made most efficiently here.

Product development and design in turn relies heavily on the access to and use of relevant information (Hubka et al. 1988, Hicks et al. 2002), which is thus a prerequisite for making knowledge based decisions. Identifying which information on sustainability issues, other than product and process data might be of interest, has not been explored much in research or practice. For firms working to minimize negative sustainability impacts of products today, knowing what information to look for and where might seem like a daunting and

demanding task. Consequently, the present research work is an attempt at developing an understanding of what sustainability information relevant to product development and design is, where such information can be found, and how it can be compiled to facilitate the use of such information in product development and design.

1.1 The centre for research-based innovation; SFI Norman

How will the above described trends and dilemmas influence the Norwegian manufacturing industry in the years to come, an industry which operates in a high-cost country and which also competes on the global market? The answers to these questions are searched for in the SFI Norman program. SFI Norman was established in 2007 by the Research Council of Norway as a Centre for Research-based Innovation. It is an eight-year long research program with the vision to develop new and multi-disciplinary research on next-generation manufacturing, to create theories, methods, models, and management tools that may enable Norwegian manufacturers to thrive in global competition. It includes product development in which the goal is to develop a collective set of activities, including ideation, invention, development and production, needed to bring to the market place new products that provide more value to customers than alternative offerings. The focus is on the unmet need or problem (customer want), the solution (technology and thing), the human knowledge needed, and the commercially successful use (of the solution) in the market place (SFI-Norman 2011).

The present research project participates in, and is funded by the SFI Norman project. Hence, an important ambition is to make a contribution to the overall SFI Norman objectives within the field of product development. The next section will elaborate on this effort.

1.2 Research objectives and questions

An important motivation for taking on this research was to help firms in their efforts to improve the sustainability performance of their products, as sustainability may be one way of adding value to products beyond traditional aspects like functionality, quality, and cost, and thus increase firms' competitiveness. Developing more sustainable products is considered a journey rather than a destination: a challenging journey as environmental and social impacts from products may occur at all life cycle stages and involve a large number of stakeholders, most of them outside the firms' control.

Viewing product development and design as a process which rests heavily on information to achieve its main tasks (Hubka et al. 1988, Hicks et al. 2002), seeking out relevant information on sustainability issues may be a key to creating increased sustainability

knowledge and awareness in product development and design. This may further enhance firms' ability and opportunity to develop and manufacture more sustainable products.

The main objective of this research project is therefore to explore if there is interesting and relevant information regarding sustainability issues "out there" that could be useful to manufacturing firms in their efforts to develop more sustainable products. More specifically, the goal has been to *identify* relevant sustainability information, and to explore how such information may be *collected* and *compiled* for efficient exploitation in relation to product development and design. In addition, the goal has been to explore what types of sustainability information manufacturing firms themselves consider important to product development and design and how accessible this information is, in addition to factors that influence such considerations.

Currently, there is no available literature describing what sustainability information is, or what types of such information firms find relevant to product development and design. The present research project therefore acknowledges that it is premature to explore the practical exploitation of sustainability information in industrial practice. Instead, the objective has been to build theory and add to the general knowledge base within this field. The objectives developed for the present research project are therefore:

1. To explore and contribute to an understanding of what sustainability information relevant to product development and design is, grounded on existing body of scientific literature.
2. To investigate and identify what sustainability information manufacturing firms find important and accessible to product development and design, and the key variables that influence such considerations.

Based on the two main objectives developed, a three year long research project was conducted with the following more specific research questions:

- RQ1: How can sustainability information relevant to product development and design be identified, collected, and compiled?
- RQ2: What sustainability information relevant to product development and design is considered important and accessible to Norwegian manufacturing firms?
- RQ3: What are the key variables and factors which influence perceived importance and accessibility of sustainability information in Norwegian manufacturing firms?

Before trying to answer these research questions, it is necessary to explore what motivation firms should have to consider developing more sustainable products. As already stated,

sustainability may be one way of adding value to products beyond traditional aspects like functionality, quality, and cost, and thus increase firms' competitiveness. But what is the meaning of "added value" to customers?

On one hand, the present research project considers sustainability as a way of generating new meaning to products. All products have meaning (Verganti 2008, 2009), and some of the most successful firms in history were those which searched for radical new meanings in products before their competitors (e.g. Apple, Artemide, Toyota). Meaning in this sense may according Verganti (Verganti 2009) be individual motivation linked to psychological and emotional meaning as in: *"when I use this T-shirt I feel good about myself because I know children were not involved in making it, and it is made from ecological cotton"*. Meaning may also imply social motivation linked to symbolic and cultural meaning as in: *"when I drive this specific car, it says to others that I care about the environment"*. Hence, sustainability may be a way of adding new meaning to products.

On the other hand, firms are facing increasing pressures from stakeholder groups to improve their overall social and environmental performance (Madsen and Ulhøi 2001, Cramer 2002, Delmas and Toffel 2004). This trend implies that firms will need to focus on creating value not only in financial terms, but also in ecological and social terms. In particular, the emergence of a civil regulation, driven by increasing transparency and communication through e.g. internet is an important driver in this context (Cramer 2002). Twitter, YouTube, Instagram, Facebook, and other social media on internet offer indefinite possibilities for end-customers, concerned citizens, and NGOs to advocate their views, thus re-distributing the traditional power structures in society. Hence, sustainable business through offering more sustainable products is steadily becoming a requirement for survival in today's increasingly transparent markets.

The five research articles included represent and describe the main results from the present research project and summarize the efforts to identify, collect, and compile sustainability information relevant to product development and design. The relationship between the research questions and the article contents is illustrated in Figure 1-1, which is inspired by Lundteigen (Lundteigen 2009:9).

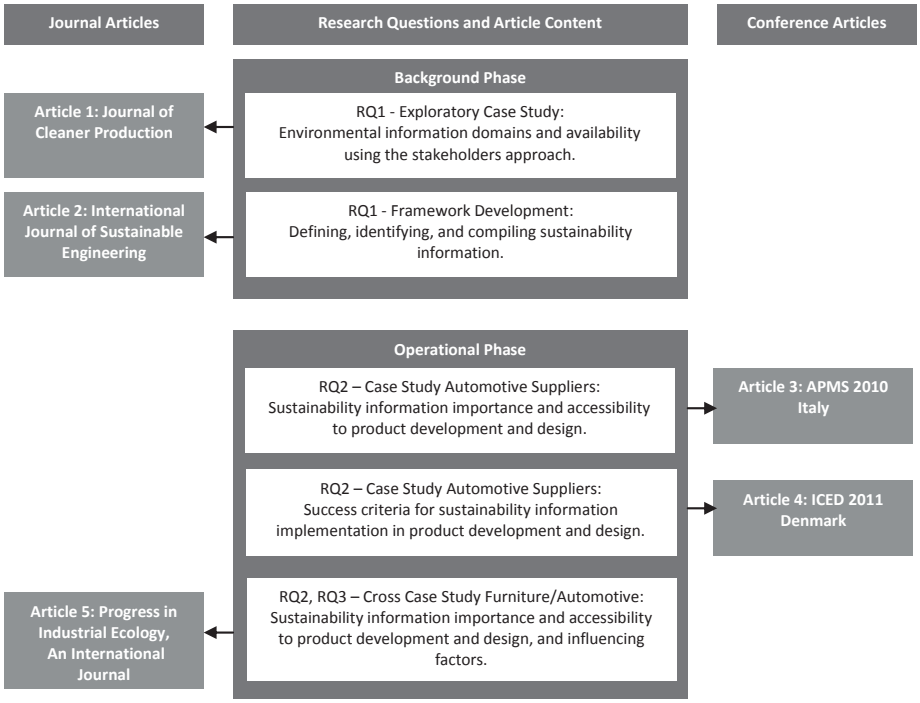


Figure 1-1: The relationship between research questions and articles produced

1.3 Limitations

The main content of this thesis is sustainability information relevant to product development and design in manufacturing firms. It is a broad research area grounded in systems view in which all limitations can be questioned (Arbnor and Bjerke 2009). The most important limitations that should be recognized, however, based on this author's opinion are:

- Product development and product design have not been differentiated. It is recognized that many different definitions of product development and product design exist. However, in this project their relevance to sustainability information is considered the same, hence product development and design have not been differentiated, but are treated as one entity.

- Sustainability may in a literal sense be anything depending on which definition is employed. This research project is based on Elkington's triple bottom line (TBL) definition (Elkington 1998). The motivation for using this definition in the present work is described in Appendix C.
- This research focuses on the development of physical products, not product service systems and the like. There might be other types of information considered important and relevant to product service systems than to development of physical objects.
- New product development and incremental product development have not been differentiated, as the importance and relevance of sustainability information in terms of creating knowledge is considered similar to both.
- The present research project does not consider IT systems or other information management systems in connection with sustainability information or the integration interface with such systems. IT systems supporting information and knowledge management already exist in abundance (Erlandsson and Tillman 2009); consequently the development and use of such systems lies outsides the scope of the present thesis.
- Studying exploitation of sustainability information in firms has not been an integral part of the research work in the case studies. The main objective has instead been to build new knowledge on what sustainability information is. A discussion on how this researcher envisions its use has, however, been included in Section 4 based on theory.
- The sustainability framework developed in this thesis was developed within systems theory (Arbnor and Bjerke 2009), meaning the framework must be viewed based on the sustainability information elements themselves as well as their organization. The organization of the framework is that of stakeholder groups; these may vary between firms and the problems at hand. Therefore, only the most common stakeholder groups have been incorporated into the framework. The framework belongs to an open system with continuous interaction with the environment, and is as such expected to change over time. Consequently, the framework represents available sustainability elements of today. In the future, other sustainability elements may become more relevant than those described in this thesis.
- Finally, this research project deals with sustainability information in the context of the Norwegian manufacturing industry. There might be cultural issues in the Norwegian context that are taken for granted and thus become a blind spot during analysis and discussions of results.

2 Theoretical background

The starting point of this research project was an initial state-of-the-art review on sustainability information relevant to sustainable product development and design. The purpose was to develop an initial understanding of what had already been done by other researchers. The complete review is presented in Appendix A.

Research literature explicitly examining sustainability information in product development and design, beyond process and product data, was found to be scarce. Several "calls" for more information were identified within the field of innovation (Foster and Green 2000), and within ecodesign and sustainable development (Baumann et al. 2002, Waage et al. 2005, Lindahl 2006, Lofthouse 2006, Le Pochat et al. 2007). The main body of literature, however, examines sustainability information in other contexts like social and environmental disclosure (Larsen 2000, Frieder 2002, Line et al. 2002, McMurtrie 2005, Moffat and Auer 2006, Brown et al. 2009, Prado-Lorenzo et al. 2009, Tagesson et al. 2009), IT systems for environmental information management (Carlson et al. 2001, Frysinger 2001), or knowledge acquisition through stakeholders (Roy and Thérin 2008, Bos-Brouwers 2009). The importance of stakeholders is also emphasized by Alniacik et al. (Alniacik et al. 2010) who argue that stakeholders are vital to modern business success. The most comprehensive work on information identified in literature is the one of Erlandsson and Tillman (Erlandsson and Tillman 2009) concerning corporate environmental information collection, management, and communication, which identifies stakeholders as important influencing factors, although the study predominantly focuses on product and process data.

Based on this state-of-the-art review, an important gap in extant research literature was identified within the field of sustainability information relevant to product development and design. In the reviewed articles, there is a lot of talk about information; however, most researchers only indicate the importance of information in relation to product development. Except for Erlandsson and Tilmann (Erlandsson and Tillman 2009), and Foster and Green (Foster and Green 2000), few attempts have been made to identify or clarify what such information could be. In addition, the terms information and data are often used interchangeably, and there is a predominance of literature describing sustainability related product and process related data, not information. The context for which the information and other data are intended, is sometimes missing or unclear. None of the reviewed articles included a definition of sustainability information relevant to product development and design. Finally, an important finding is the predominance of literature describing stakeholders in relation to such information flows. This indicates that stakeholders could be

a viable approach for identifying, collecting, and compiling sustainability information. Hence, based on this initial review, a contribution to the general body of knowledge can be made by this research project in answering the research questions in Section 1.2.

Further initial theoretical studies were undertaken as background research in order to be able to conduct the case studies. The field of study in this project is very broad; thus a multidisciplinary approach was necessary. Figure 2-1 demonstrates the main domains of literature used and where further descriptions of these fields may be found. This theoretical background information has predominantly been included in the Appendices as demonstrated in Figure 2-1 in order to enhance the readability of this thesis.

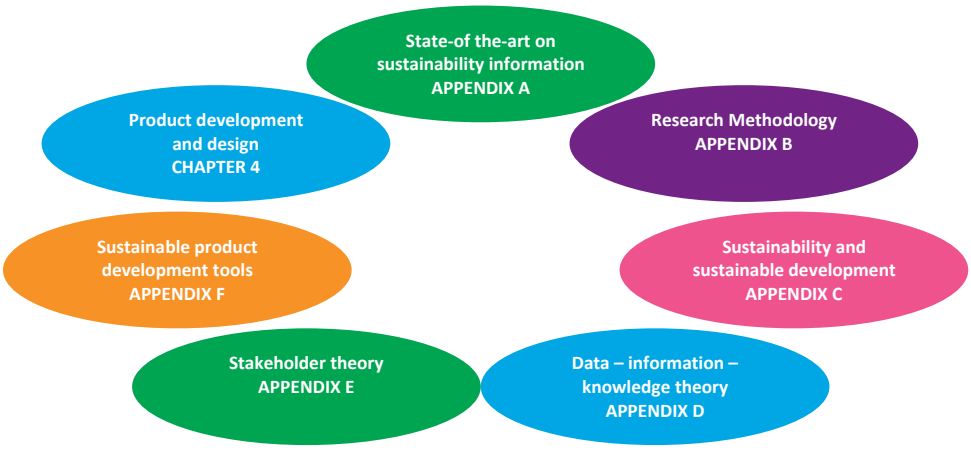


Figure 2-1: Overview of the main domains of theory used in this research project

2.1 Defining sustainability information in a product development and design context

For the present research project, a clear cut context-dependent definition of sustainability information was required, a definition that relates to product development and design and which incorporates a specific definition of information to avoid misunderstandings vis-à-vis data and knowledge. Moreover, the definition had to indicate which sustainability approach was taken, since a great variety of approaches are found in literature as described in Appendix C (UNEP 1987, Elkington 1998, Ehrenfeld 2008, Epstein 2008, Rogers et al. 2008, United Nations Environment Programme 2009). According on the initial state-of-the-art review, the importance of stakeholders in relation to information had also been established by several other researchers as reported in Appendix A (Foster and Green 2000, Erlandsson and Tillman 2009).

Using a pragmatic approach, a new definition on sustainability information for the present research project was developed, grounded on the triple bottom line concept (Elkington 1998), information and knowledge theory (Nonaka 1994, Court 1995, Hicks et al. 2002), and stakeholder theory (Freeman 1984, Donaldson and Preston 1995, Andersen and Fagerhaug 2002). Combined, as it describes the major contents of this research project, the following definition of sustainability information was developed:

"Stakeholder information elements potentially capable of contributing to knowledge in product development and design, combining the environmental, social, and economic dimensions of sustainability".

Sustainability information (SI) explicitly includes information beyond internal product and process related data commonly used in product development and design today. It also includes sustainability expectations from firm stakeholders, towards the product itself, or towards the firm, as well as more informal sustainability signals between the stakeholders.

This definition of sustainability information may be theoretically questioned, and other definitions may be developed grounded on other theories, but for the purpose of the present research project, this definition has proved its usefulness and viability.

3. Research methodology and approach

Research may be defined as the creation and development of knowledge, where the output is contribution to knowledge (Karlsson 2009). Wikipedia, defines research as a scientific search for knowledge in order to establish new facts, solve new or existing problems, prove new ideas, or develop new theories (Wikipedia 2011). Other definitions include investigation aimed at the discovery and interpretation of (new) facts, revision of already accepted theories and laws, or practical application of such new theories or laws (Merriam-Webster 2011b). The Norwegian Research Council describes the purpose of research as generating more insight and promoting scientific and knowledge-related development (Reserach-Council 2011). Summarized, research is about acquiring and generating new knowledge (knowledge creation), based on the works of previous researchers.

A more thorough presentation of research methodology, case research, the operative paradigm, and analysis is presented in Appendix B. This chapter includes main points only.

3.1 Research perspective

Many researchers conduct research without reflecting critically on their own underlying assumptions about reality, their own values, their own conception of science, and their own scientific ideals and so on. Such assumptions may vary from researcher to researcher, and impact how problems, techniques, and knowledge are viewed in general. These assumptions become a guide for how knowledge is created in research (Arbnor and Bjerke 2009).

Before developing a research methodology, reflections were made upon positioning the present research within the larger research paradigms. Several categorizations of research paradigms have been suggested by other researchers, among them Arbnor and Bjerke (Arbnor and Bjerke 2009). They have classified three main methodological views, the analytical view, the systems view, and the actors view and placed these within the larger research paradigms as presented in Table 3-1 on the following page.

Table 3-1: Some characteristics of the three methodological views based on Arbnor and Bjerke (Arbnor and Bjerke 2009)

Objectivist – Rationalistic Conception of Reality ◄——————————► Subjectivist – Relativistic Conception of Reality

	Analytical view	Systems view	Actors view
Assumptions of reality	The whole, which is factive, is equal to the sum of the parts.	The whole, which is factive, is not equal the sum of its parts. Both the sum of wholes and the way they are put together provide information.	A socially constructed reality that has different levels of meaning and understanding.
Knowledge	Knowledge independent of individual observers. Descriptions and explanations of reality are general and absolute.	Knowledge dependent on system. Descriptions of reality are pictures of systems and parts. These pictures are not general, but valid for specific classes.	Knowledge dependent on individual and the knowledge creator. Based on how actors perceive, interpret, and act in reality.
Explaining or understanding	Explaining. Causal relations are sought, as deterministic relations or stochastic relations.	Explaining or understanding. Seeks relations among forces and their results as explanations, or comes up with representative interpretations for understanding.	Understanding. Seeks to understand and describe ambiguous relations that are continuously reinterpreted and given different meaning.
Result	Verified hypothesis.	A better explanation or understanding of the behavior of the different classes of the system.	Knowledge of those processes that socially construct reality will grow through understanding.
Methods for creating knowledge	Representative cases	Typical cases or partly unique cases	Interactive action. Dialog with the actors in the researcher area. The researcher becomes part of the process through action.

The present research project is grounded within the systems view. The systems view is strongly rooted in the philosophies of systems theory, holism, and structuralism (Arbnor and Bjerke 2009). Arbnor and Bjerke have developed five guiding principles for the systems view which will be addressed in line with the present research project:

1. The totality principle
2. The complexity principle
3. The relativity principle

4. The mutuality principle
5. The principle of unpredictability

1. The **totality** principle implies that in a complicated world, the various parts are more or less dependent on each other (the totality).

The main purpose of this research project is to identify, collect, and compile sustainability information, that when used, creates knowledge and awareness on sustainability issues, and thus enhances firms' opportunity and ability to develop and manufacture more sustainable products.

Sustainability information as defined and used in this research project implies that everything more or less depends on each other. Sustainability information which may or may not contribute to knowledge depends on the stakeholders as information domains. The stakeholders depend on the firm in question, or may even be product or situation specific. The potential of contributing to knowledge depends on who receives the information. A common view is to describe the generation of knowledge as within-person capacity (Nonaka 1994, Court 1995). Hence, the potential for sustainability information of contributing to knowledge depends on the recipient's previous knowledge in this matter, professional training, the recipient's values, beliefs, and so on. As a consequence, the research project has defined several limitations which are related to the next principle, the complexity principle.

2. The **complexity** principle implies that every systems model or interpretation is a limited picture or view of reality. External and internal delimitations have to be made for practical reasons based on the problem at hand. All delimitations can further be questioned, since real systems are multidimensional, and there are many options to choose from.

Sustainability information flows forms a corner stone in this research project. These information flows are suggested to flow between the firms and their stakeholders, and also between different departments, functions, and individuals within the firms. As a total, this constitutes a very complex system. Defining stakeholders as *"anything or anyone influenced by the firm"* (Donaldson and Preston 1995), there is no real end to how many individual stakeholders the firms depend on. The systems view allows for simplified models to explain reality, hence, stakeholder groups are used instead of stakeholder

individuals. Moreover, limitations have been made to the number of stakeholder groups included in the present research project as described in Appendix E.2. To further delimit the present research project, different ways of creating knowledge based on sustainability information, have not been part the present project (ref. Appendix D.2). More limitations that apply have previously been described in Section 1.3. It is recognized that these limitations may be questioned, and that other limitations not described here may also exist, due to the complexity of the sustainability information "system".

3. The **relativity** principle states that system pictures are partly dependent on who constructs them i.e. there are no absolutely true or false systems, but more or less comprehensive systems that are more or less dependent on the frame of reference of the researcher.

In Appendix B.1, the social science paradigm describes this issue in relation to the scientific theorist Törnebohm (Törnebohm 1974). Knowledge gained through the researcher's education may affect the concepts and beliefs that are studied, as opposed to viewing the researcher as more objective without influencing the research. In relation to the present research project, this implies that the sustainability information framework is affected and "flavored" by the researcher that constructed it. The compilation of this framework has been a long process involving e.g. theoretical background work, a practical case study (ref. Article 1), more theoretical work, extended literature search, interpreting and understanding the results from the literature search, and finally compiling sustainability information into a framework. In all these phases, this researcher's conception of science and understanding of meaning have affected the final outcome and the system (framework) description. Since meaning again is dependent on individual factors like professional training, values, beliefs, etc. (Nonaka 1994), other researchers might have understood, formulated, and compiled the information elements differently, based on their comprehension of meaning and reality. Hence, a described system (framework) of sustainability information elements is dependent on the researcher that constructs it. The present framework is not absolutely "true", but is nevertheless a comprehensive framework based on available scientific literature between 2000-2010. Based on systems theory, it is acknowledged that other frameworks might be just as "true" as the one developed in the present project.

4. The **mutuality** principle implies that producers (variables) and products can change places in different systems models.

In the system model formulated in the present research project, the sustainability information framework, firm stakeholders are regarded as the information domains, i.e. the variables or producers of information elements with regards to systems theory. In this model, the individual information elements may be regarded as the product, the result, as they (i.e. the information elements) depend on the stakeholder in question. As producer and product may change in different system models, another model could regard the information elements as the producers (variables) and the stakeholders as the products. In such a model the information elements could be regarded as way of describing different characteristics of the stakeholders. Consequently, it would be possible for the producers and products to change places in the present model.

5. The principle of **unpredictability** concerns the way a system is constructed. As the system is in continuous interaction with its surrounding environment, there will be a limit to predicting the system models' future.

The present research project is grounded on extant scientific literature, which the sustainability information framework has evolved from. The framework has evolved from today's understanding of sustainability, and as such, the framework may look different in the future, if the future society's values, cultures, etc. develop a different understanding of what sustainability is. This different understanding of sustainability will also be reflected in future scientific literature, hence, if the same work were to be performed 20 years from now, based upon scientific literature from the period 2020-2030, it is very likely that a sustainability information framework would consist of different information elements than the ones described today. This issue is further elaborated in Section 8. Consequently, it is acknowledged that the sustainability information framework presented here is more or less true today, but, that there is a limit to predicting its future.

Concluding, within research paradigms, there are no true or false views. There are only different ways of looking at the reality of the world, which again shapes how knowledge is created. The present research project is grounded in the systems view. It is acknowledged that researchers within other methodological views may provide other answers to the research questions developed in this project, answers which are just as true as the ones put forward here.

3.2 Developing a methodology for the present PhD project

A methodology is basically the steps and guiding principles for creating knowledge. In order to create knowledge as part of this PhD project, the project was organized into three main phases based on deliverables: 1) the development of a PhD project plan, 2) the development of research articles, and 3) the PhD thesis development as demonstrated in Figure 3-1.

The research activities started with an initial literature review and identification of a study area, i.e. a research gap as presented in Appendix A was described. This was followed by a preliminary formulation of research questions and a research approach which were included in the PhD project plan. The greatest difference between the original research plan and the final research project is the gradual transition from the environmental perspective to the sustainability perspective. First, the plan was to study environmental information in relation to product development and design, as described in Article 1. Through the first exploratory case study conducted, it was learned that there was more interesting information to be found among external stakeholders, in addition to information purely within the environmental domain. This concerned mainly information within the social and ethical domains that could also potentially affect decisions in product development and design. Thus, after the first case study, sustainability information became the focus of the remainder of the project.

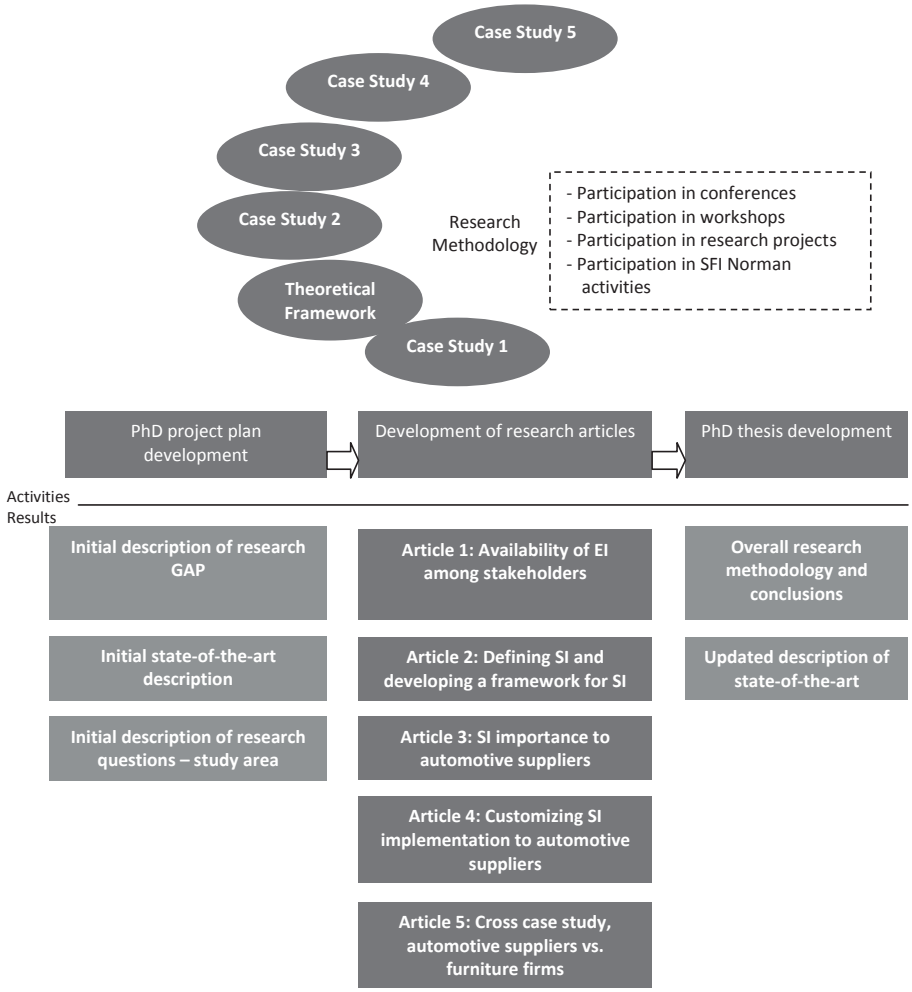


Figure 3-1: PhD Project execution plan – adapted from Lundteigen (Lundteigen 2009)

The research topic sustainability information relevant to product development and design in manufacturing firms lies within the field of operations management. Operations management is about transforming human, physical, and information resources into

products and services, and exists in all functional areas of a company (Karlsson 2009). Within operations management, case research is considered one of the most powerful research methods. Furthermore, case research is also considered suitable for creating knowledge within the systems view. As reality according to the systems view is perceived to consist of systems with interdependent relations on one hand, and typical or sometimes partly unique cases on the other (Arbnor and Bjerke 2009), different case studies were chosen as the main methodology. A more thorough explanation of the rationale behind each case study is to be found within the Appendix B.

In addition to the five case studies, other research activities included the development of a theoretical framework for sustainability information grounded on stakeholder theory. The development of this framework included extensive literature searches for sustainability information in different scientific database as described in Article 2. Once the framework had been developed, multiple case studies were carried out based on it. Other activities carried out which also have influenced the work and inspired new ideas and insights:

- Participation in three different conferences with different topics, research communities and locations (EcoDesign 2009 in Sapporo, APMS 2010 in Como, ICED 2011 in Copenhagen). At the conferences full paper presentations were been given. Just as important, meeting other researchers and PhD candidates provided opportunities of inspiring discussions.
- Participation in the IMS Summer School 2010 in Zurich where the present research plan and results generated at the time were presented. This contributed to useful discussions on different research paths for the remaining work.
- Participation in the SUM (SUstainable Manufacturing of light weight solutions) project funded by the Norwegian Research Council through workshops, seminars, and by writing a state-of-the-art report on ecodesign.
- Participation in the course Research Methods in Operations Management in 2009 hosted by EIASM in Brussels. This course gave good insights into different types of case studies, surveys, and action research.
- Participation in seminars and courses related to the SFI Norman project on various topics useful for researchers: presentation techniques, writing articles, academic writing, and action research. In addition, general workshops and seminars hosted by SFI Norman gathering representatives from academia and industry have been useful in getting feedback on present research. Several presentations have been given on these occasions.

Finally, this PhD thesis ties it all together by including an updated literature review, by describing the overall research methodology, and by presenting research questions and results.

3.3 Research quality and validation techniques

The systems view implies a generally lower degree of generality and absoluteness compared to the analytical approach, as it is not possible to test definite relations among the variables in the system studied, check the order between them, or check the importance of intervening variables. Instead, the systems view takes a more pragmatic position in which what a measurement can be used for, not the way the measurement was made or its precision is focused. (Pragmatisme: "*a school of philosophy based on the principle that a scientific result is judged by its usefulness, workability, etc. when applied in the empirical world"*) (Arbnor and Bjerke 2009).

According to Yin (Yin 2009), it is nevertheless possible to judge the quality of the research methodology based on certain logical tests. Basically, there are four tests common to social science methods: 1) construct validity, 2) internal validity, 3) external validity, and 4) reliability. In the following, how the research project has dealt with and met the different validation techniques will be addressed.

- Construct validity is about identifying fitting operational measures for the concepts that are being studied. When studying environmental and sustainability information in firms, several sources of evidence were used to make sure that findings were supported by multiple data sources. For instances, when doing interviews, documents were used to support or contradict statements made by the interviewees. Furthermore, to prevent misunderstandings, a meeting was always arranged with the case firms after completion of the data collection and analysis. In these meetings, tentative conclusions were presented and discussed. Drafts and final reports were also sent to the case firms for review.
- Internal validity is about seeking causal relationships, were some conditions are believed to lead to other conditions. Addressing this issue was done during the data analysis phase where one tried to find explanations based on the evidence present. This challenge was the most difficult one to meet as a single researcher. Therefore, tentative conclusions were continuously discussed with supervisors. Moreover, other colleagues were also used for discussions on analysis and tentative conclusions. Several presentations were given at international conferences during the course of the research project, at which conclusions were discussed with other experienced researchers.

- External validity concerns defining the domain to which a study's findings can be generalized. This issue was addressed by designing the main research around four case studies in Norwegian manufacturing firms, using replication logics.
- Reliability is about demonstrating that the operations of the study can be repeated by another researcher, with the same results. An important prerequisite for such is to document in a research protocol all procedures and steps taken, and to develop a case study database. For each case study and each step of the research, detailed research protocols were developed to describe what has been done. Moreover, care was taken to document what was actually done during the coding and analysis process, and to store all evidence in a case study database. Replicating the case studies should therefore be possible.

The Norwegian Research Council has another approach to evaluating research quality (Lundteigen 2009). High quality research should, should according to the Research Council, be evaluated according to the following criteria:

- Originality: to what extent the research is novel and may be used innovatively in theory or methods.
- Solidity: to what extent the statements and conclusions in the research are well supported.
- Relevance: to what extent the research is linked to professional development or is practical or useful to society.

The articles that are part of this research project have been published at conferences with anonymous peer reviews (Article 3 and 4). In addition, the articles submitted for publication in journals (Article 1, 2, and 5) were peer reviewed anonymously. Peer reviewing is a good way of ensuring that the research approach and results fulfill the requirements of originality, solidity, and relevance. Presenting the work at conferences and getting feedback from a larger group of researchers and industry people is further confirmation of research relevance. Finally, the overall research objective is seeking out relevant information on sustainability issues may create increased sustainability knowledge and awareness in product development and design. This may further enhance firms' ability and opportunity to develop and manufacture more sustainable products. Supporting firms in their journey and efforts to develop more sustainable products should therefore be valuable both to industrial practice as well as to lager society.

4. Product development and design

4.1 Product development and design as an information process

Product development and design processes vary greatly from one firm to another. Some firms are very unstructured and may not be able to describe their process, whereas others follow a detailed development process (Ulrich and Eppinger 2008). Prescriptive and normative models for product development and design have been developed in order to support design work through rationalizing creative work, through permitting design to be taught and transferred, through improving communication, through reducing the likelihood of forgetting something important, through facilitating planning (Gericke and Blessing 2011), and through increasing the probability of achieving successful solutions (Hubka et al. 1988). The increasing complexity of new design problems (e.g. new materials, new technologies, and new meanings) also requires a more multi-disciplinary approach which implies more directing of tasks into subtasks as well as knowing when the various specialists shall contribute in the process (Cross 2008). In this increasingly growing complex process, the use of structured sustainability information may be one way of initiating and formalizing knowledge on sustainability issues in firms, and thus encourage firms' ability to develop more sustainable products.

The difference between product development and design is vague and depends greatly on the researcher. Many definitions of design are close to those of product development (Verganti 2008). Product design may be seen as "*the professional service of creating and developing concept and specification that optimize the function, value, and appearance of products and systems for the mutual benefit of both the user and manufacturer"*, a definition which is broad enough to include all activities by a product development team (Ulrich and Eppinger 2008). Another approach is to describe design as what deals with the meaning people give to products, or more precisely, one could say that design is about making sense "of things" (Verganti 2008). The design process is typically described as consisting of four steps; problem analysis, conceptual design, embodiment of design, and detailing (Cross 2008, Gericke and Blessing 2011). However, product development is often described as including six steps; planning, concept development, system-level design, detailed design, testing and refinement, and finally production and ramp-up (Ulrich and Eppinger 2008). Product development may be defined as "*the sequence of steps or activities which an enterprise employs to conceive, design and commercialize a product"* (Ulrich and Eppinger 2008), or as "*... all those activities directed at improving or designing*

new products, from the initial emergence of a product concept idea up to production ramp up" (Forza and Salvador 2001).

No matter which approach is taken to product development and design, a common feature of the two is their dependency of information in order to achieve core activities (Hicks et al. 2002). Hubka (Hubka et al. 1988) for instance, describes the design process as a sequence of transformations, in which the transformations involve processing of information. Cross (Cross 2008) emphasizes the importance of actively searching for information, and of summarizing information regarding the problem formulation into requirements. This is one of several keys to successful product design. Information is further viewed as necessary for initiating and formalizing knowledge (Nonaka 1994). Court (Court 1995), for instance, describes knowledge as the ability of individuals to understand information, including how they handle, apply, and use it in a given situation. Sustainability information in the present research projects therefore becomes sustainability knowledge when the product designer understands the information, can handle, apply, and use the information in a product development and design context. This knowledge is again necessary for making knowledge based decisions throughout the entire product development and design process.

A frequently mentioned paradox, "the design paradox", deals with knowledge in a product development and design context. In the early phases (e.g. analysis and conceptual design), knowledge about the product is limited, but the freedom of design is still great. In the later phases, product knowledge has increased, but then the freedom of design has decreased accordingly (Lindahl 2005, Luttropp and Lagerstedt 2006). In addition, environmental impacts and social cost factors are reported to be largely determined in the early phases of product development and design (Charter and Tischner 2001, Maxwell and van der Vorst 2003, McAloone and Bey 2009). Consequently, changes to the sustainability attributes of products can be made most cost-efficiently in these initial phases and which should also be the main "target phases" of sustainability information.

Figure 4-1 demonstrates relations between freedoms of design, the development phase, and designer knowledge. The figure is based on the figures of Lindahl, Luttropp and Lagerstedt (Lindahl 2005, Luttropp and Lagerstedt 2006). As demonstrated in the figure, sustainability information use in product development and design may possibly have greatest impact in the early phases, while the freedom of design is great, and cost-efficient changes can still be made to the sustainability attributes of the product. Moreover, the use of sustainability information in the early phases may be a way of reducing the gap between designer knowledge and designer freedom, as sustainability information may increase designer knowledge. This is demonstrated through the purple and red dotted lines in Figure 4-1.

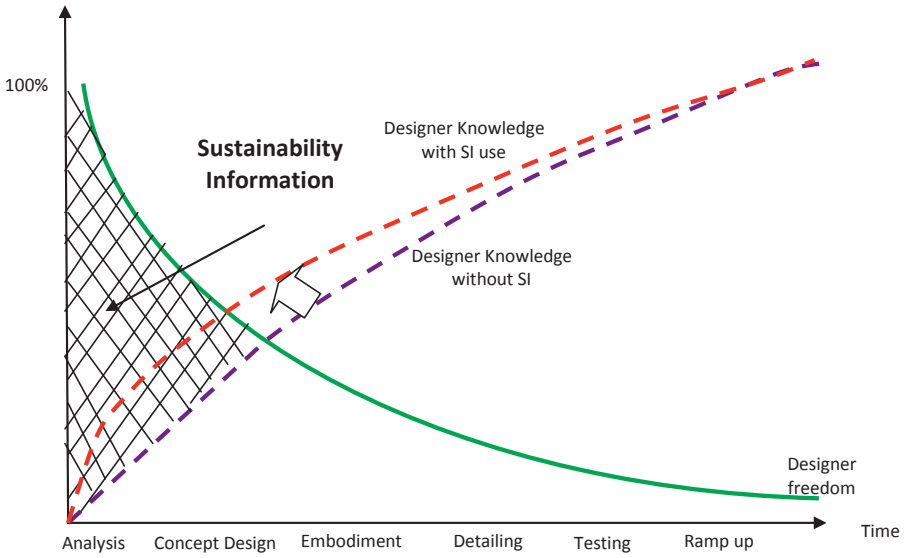


Figure 4-1: Sustainability information reducing the gap in "the design paradox"

Although sustainability information is considered most effective in the initial phases of product development and design as demonstrated in Figure 4-1, the information may be used for creating knowledge in all phases and thus allowing knowledge based decisions to be made in line with current strategic priorities in firms.

4.2 Sustainability in product development and design

Current demands in product development and design are increasing. There is a constant pressure to reduce costs and lead time, to avoid costly mistakes and delays, to increase the quality of the product and maximize functionality. In addition comes requirements to provide the customer with a benefit, to fulfill the customer's needs or desires (Luttropp and Lagerstedt 2006, Cross 2008), or to design products with new meanings (Verganti 2008).

A traditional way of viewing sustainability in product development and design is to say that sustainability demands and regular demands must be balanced against each other as demonstrated in Figure 4-2. A product should be produced with a minimum of ecological damage, human health damage, resource depletion, and with a minimum of negative social impacts across the entire supply chain. In addition, the product should have positive societal impacts, contribute to economic growth, community development, and stakeholder engagement, etc. (United Nations Environment Programme 2009). It is argued that these sustainability demands must be balanced against traditional demands (i.e. functionality, quality, and cost) because, if a product fails to fulfill its basic functionality, there will be no customers. When there are no customers, there will be no market, no profit, and finally the firm will cease to exist (Luttropp and Lagerstedt 2006). Due to this interdependence between sustainability demands on one side and traditional demands on the other, it is argued that sustainability should be incorporated into existing methods and work practices (Luttropp and Lagerstedt 2006). Following this line of reasoning, sustainability information may be used in existing methods and practices for product development and design in generating knowledge on "demands". These "demands" may be used in describing problem statements, limitations and requirements, i.e. predominantly in the analysis or planning phase of product development and design. Information on current or future regulations regarding sustainability issues, or requirements for sustainability-labeling or certificates are examples of sustainability information used as a "demand".

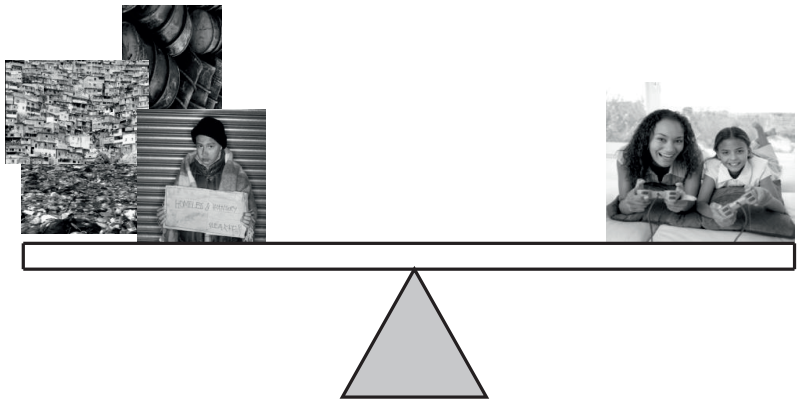


Figure 4-2: The balance between traditional customer demands (right side) and sustainability demands (left side), modified from Luttropp and Lagerstedt (Luttropp and Lagerstedt 2006)

Rather than viewing sustainability in product development and design as a demand, another approach is to view sustainability as an innovation opportunity by designing new products with entirely new meanings. Verganti's (Verganti 2009) strategy for design driven innovation starts with understanding of unspoken and subtle dynamics in social-cultural models and results in the proposal of radically new meanings that may require a change in current social-cultural regimes. These meanings constantly reflect the psychological and cultural dimensions of being human. Meaning may imply individual motivation linked to psychological and emotional meaning, or meaning may imply social motivation linked to symbolic and cultural meaning. Values, beliefs, norms, and traditions influence how meaning is given to products in a culture, which again is a reflection of personal lives and society (Verganti 2009).

It is argued that radical innovation of product meanings is rarely pulled by users, but is rather proposed by firms (Verganti 2009). In traditional user-centered design, firms try to understand how people currently give meanings to products, often to discover that this meaning has already been proposed by other firms. In Verganti's design driven innovation, interpreters are used to understand, anticipate, propose, and influence new meanings based on knowledge about future possible social-cultural evolutions (Verganti 2009). It is in this context, design for sustainability may be used as an innovation possibility by proposing new meaning to products through sustainability. How environmentally friendly the Toyota Prius car actually is, is open to discussion. The car is, however, a huge success, as Toyota was the first large car manufacturer to propose an environmentally friendly family-size car. Hence, Toyota was the first to propose a new product meaning (environmental friendliness) to customers within this car segment. When customers use this car, it says to others that the car owner cares about the environment.

By viewing sustainability as an opportunity to design new products with entirely new meanings, sustainability information may in this respect be used as a source of inspiration or to generate new knowledge on individual motivation or social motivation linked to current and future social-cultural issues. Information on social and environmental disclosures on internet (e.g. facebook, blogs, twitter) regarding products, substances, firms, and industries are examples of information that says something about current and possible future trends in society. Likewise, information on priority settings for sustainability related research calls or information on stakeholder involvement in product development to enhance learning may be ways for firms to generate knowledge on future trends which may inspire entirely new (sustainability) meanings to products.

On one hand, sustainability information may be used to generate knowledge on a demand or requirement, in which case the firm is pulled by demands in society to develop more sustainable products. On the other hand, sustainability information may be used to generate knowledge about future trends, knowledge that makes it possible for firms to propose products with new (sustainability) meanings. Instead of being pulled towards developing more sustainable products, the firm itself pushes the market and society and proposes new meanings. Figure 4-3 demonstrates how this duality is envisioned.

Figure 4-3: Sustainability information use for creating sustainable products

4.3 A model for sustainability information in product development and design

The ultimate goal of the present research project is to identify, collect, and compile sustainability information relevant to product development and design which may increase sustainability knowledge and further enhance firms' ability and opportunity to develop and manufacture more sustainable products. In order to be sustainable, these products must not only be manufactured in a sustainable manner, but the product must be sustainable across all life cycle phases (from the extraction of raw materials, processing of raw materials, manufacturing, distribution, use, end-of-life, and after-life, i.e. a cradle to cradle approach) (United Nations Environment Programme 2009) as demonstrated in Figure 4-4.

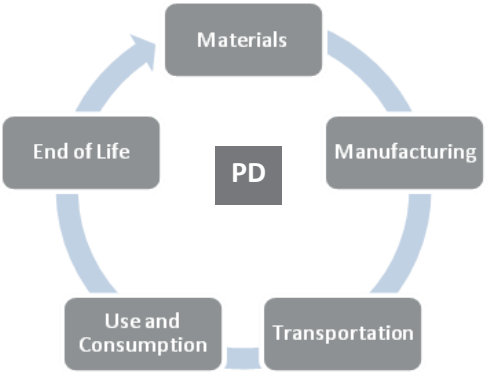


Figure 4-4: Life-cycle approach to product development (United Nations Environment Programme 2009)

This is challenging, but still necessary when developing sustainable products. Likewise, sustainability information from all life cycle phases is equally important to product development and design. The next logical question to ask is which actors are potential providers or domains of sustainability information across all life cycle phases. Obviously, this requires interaction between a great number of actors. In the present research project, stakeholders are explored as potential domains of sustainability information. As stakeholders loosely may be defined as *"anything influencing or influenced by the firm"* (Donaldson and Preston 1995) and all firms have stakeholders, independent of size, product produced, or position in the value chain, stakeholders seem likely providers to approach (Appendix E). Moreover, it has also been emphasized by others that a firm and its stakeholders are involved in a mutual exchange process of information and expectations (Andersen 2007), an exchange process which is precisely what the present research project is aiming to identify.

Combined, a conceptual model of how sustainability information relates to product development and design has been developed. This model is depicted in Figure 4-6. The stakeholders are present in the model as sustainability information domains. In the model, some of the most common stakeholder groups have been included, but other stakeholders may be added or removed based on the needs of the firm in question. These stakeholders have information relevant to various life cycle phases of a product. Suppliers for instance,

have information on extraction of raw materials, whereas governments have information on regulations regarding end-of life handling obligations. These information flows between a firm and its stakeholders represent a continuous exchange process, and move back and forth, as shown by the double ended arrows in Figure 4-5. Figure 4-5 demonstrates a simplified model of reality, as the actions taken to facilitate the information flow between a firm and its stakeholders are not included, nor is the internal information flow from various receivers in the firm to the development and design function.

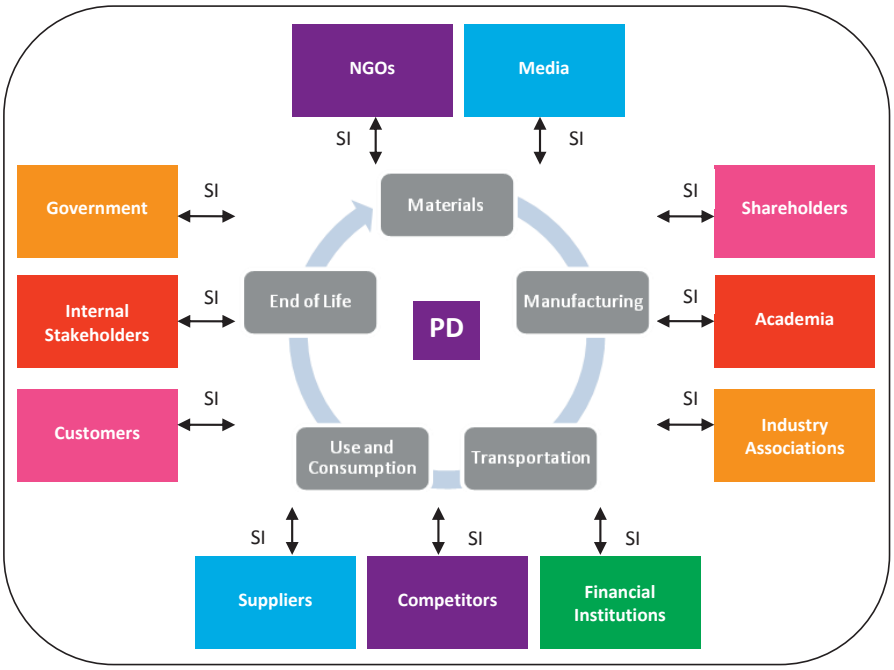


Figure 4-5: Stakeholder model for sustainability information in product development and design

In the present research project, this stakeholder model for sustainability information in product development and design has been used as the basis for the research conducted.

5. Developing a conceptual sustainability information framework

In order to be able to study sustainability information in product development and design related to the initial formulated research questions, a conceptual sustainability information framework was developed. The idea of the framework was mainly developed around the proposed stakeholder model for sustainability information in product development and design.

According to Webster's College Dictionary, a framework can be defined as *"a skeletal structure designed to support or enclose something", or "a frame of structure composed of parts fitted together"* (Dictionary 1991). Hence, the goal was to develop and structure a framework consisting of parts (sustainability information) which when used, may support the product development and design processes in firm, and collectively enhance firms' opportunity and ability to develop and manufacture more sustainable products.

Heading out, an initial explorative case study was carried out to investigate if the stakeholder approach for indentifying, collecting, and compiling sustainability information relevant to product development and design was viable (Aschehoug et al. 2012). The results from this first article (Article 1) established to a large extent, the viability of using the stakeholder approach in this context. The case study also identified an important gap between current information availability from external stakeholders and their willingness to share such information, and corresponding knowledge on information within the case firm. Having investigated this issue in industrial practice, the grounds were prepared for a more in-depth and structured process for developing the framework based on extant scientific literature. But first, more precise criteria with regards to what information to search for had to be developed. The latter has to do with information quality and is becoming increasingly important to firms (Hicks et al. 2002).

Information quality depends on the context, the problem at hand, as well as the information customer (i.e. information user); hence, no universal definition or criteria for information quality was identified in the literature review presented in Appendix D. Therefore, this research project defined its own sustainability information quality criteria as described in Table 5-1.

Table 5-1: Sustainability information quality criteria

Description	Criteria
Context: Product development and design	Importance: does the information element have the potential to be truly useful in product development and design? Can the information element potentially build knowledge on sustainability issues and thereby affect decisions or choices in product development and design?
Purpose: To develop a sustainability information framework that may contribute to build sustainability knowledge in product development and design	Accuracy: is it possible to describe the information element with some degree of exactness in the framework?
Customer: All disciplines and internal stakeholders involved in product development and design in manufacturing firms	Accessibility: is the information obtainable for the information customer, i.e. which stakeholders are involved and from where may the information be obtained?

These criteria were used for the following literature search. To ensure robustness, the development of the framework was conducted in three phases:

- Phase 1: Initial search in *Science Direct* for sustainability information published in articles between 2000-2010.
- Phase 2: Structured search in *Science Direct* and *Wiley Online Library* for sustainability information published in articles in the years between 2000-2010.
- Phase 3: Reformulating, restructuring, and compiling sustainability information into a framework.

Figure 5-1 shows the main process in developing the conceptual sustainability information framework. The process has been iterative to include feedback from journal referees that have contributed to increased understanding and knowledge on the topic on the way.

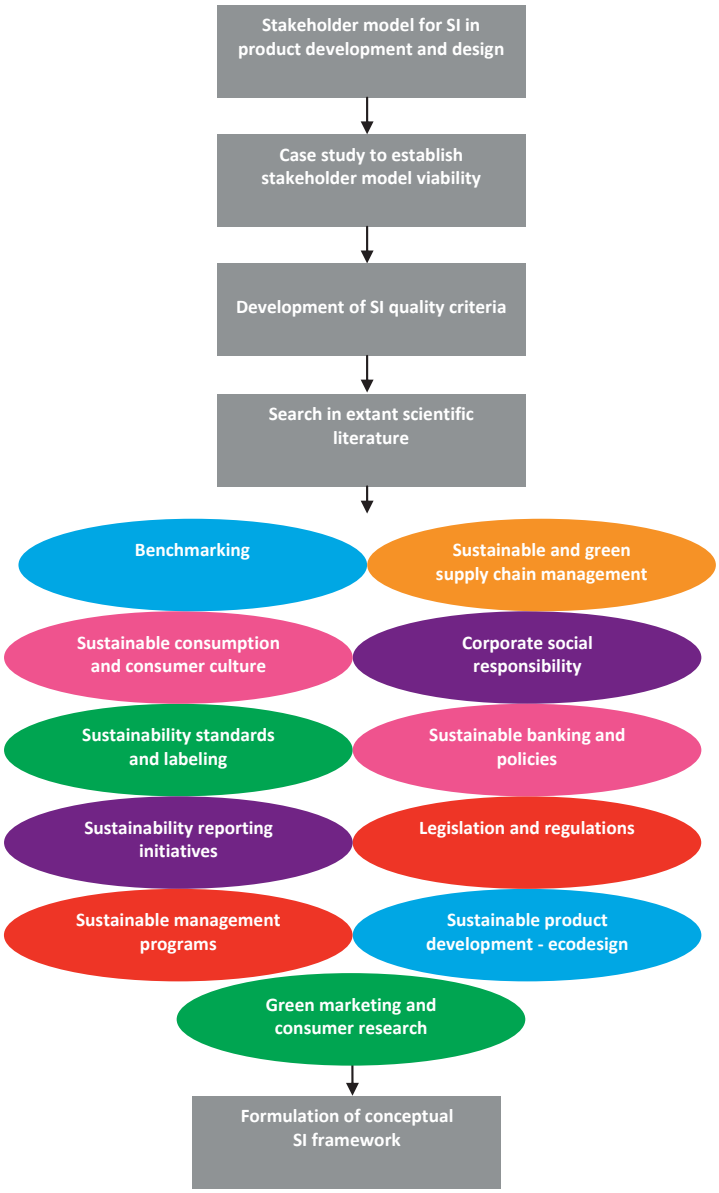


Figure 5-1: The process of developing of the sustainability information framework

Phase 1: Initial search in *Science Direct* for SI published in articles between 2000-2010.

The literature search was conducted using the e-database *Science Direct*. It was based on peer-reviewed articles from English language scientific journals with management focus, using title, abstract, and keyword search. Derived from the definition of sustainability information, examples of keywords used during the literature search in phase 1, 2, and 3 are presented in Table 5-2. In addition to the articles identified through the literature search, references in relevant articles were used as a second source for finding additional literature. Consequently, journals outside the *Science Direct* database were also identified. 125 articles were identified for an initial review, whereas 95 articles were found to contain sustainability information elements.

Table 5-2: Search terms employed in the literature search

Sustainability	**Stakeholders**	**Information**	**Product Development**
Sustainability Sustainable Environment(al) Green Ecology/ecological Ethic(al) Social Corporate social responsibility (CSR)	Stakeholder(s) Multi stakeholder Management Manager(s) Employee(s) Financial institution(s) Supplier(s) Banking/bank(s) Insurance Competitor(s) Consumer(s)/ customer(s) NGO(s) Academia/ academic(s)/university Industry association(s)/ trade association(s) Media/news/internet Government(s)/governmental/legislation Community	Information Knowledge	Product development Product design Ecodesign

Phase 2: Structured search in *Science Direct* and *Wiley Online Library* for SI published in articles between 2000-2010.

The second literature search was conducted in both *Science Direct* and *Wiley Online Library*, also with the use of the keywords presented in Table 5-2. In addition, references in relevant articles were used as a second source. Altogether, 286 articles were identified for a first review, 158 of these were found to address elements of sustainability information. The

four predominant journals containing sustainability information elements are presented in Table 5-3.

Table 5-3: Description of SI dominant journals

Journal	Journal Scope	Volumes or number of articles per year
Journal of Cleaner Production	New and prevention-oriented processes, materials, and products which are less toxic and more resource and energy efficient. Including industrial applications, environmental management initiatives, regulations, and education.	18 issues per year
Journal of Industrial Ecology	Material and energy flows studies, dematerialization, life cycle planning, design and assessment, design for the environment, extended producer responsibility, eco-industrial parks, policy, and eco-efficiency.	6 issues per year
Business Strategy and the Environment	Systems and standards, corporate environmental management tools, organizations and management, particular industry sectors, and responses of business to contemporary environmental issues, including regulations.	8 issues per year
Corporate Social Responsibility and Environmental Management	Social and environmental responsibilities in the context of sustainable development, including e.g. environmental management systems, environmental accountability, ISO 14000, policies and environmental tools.	6 issues per year
"Others"	Includes key articles from the following journals: International Journal of Management Reviews, Strategic Management Journal, European Management Journal, Energy Policy, Ecological Economics, Journal of Environmental Management, Corporate Environmental Strategy, Benchmarking – An International Journal, Robotics and Computer-Integrated Manufacturing, Futures, International Journal of Production Economics, Journal of Purchasing and Supply Management	Various

Judging from the number of publications by journal by year as presented in Figure 5-2, the large number of publications contributing indicates the broadness of the research topic. The leading journal for publishing articles containing sustainability information is *Journal of Cleaner Production* with 62 articles in total. The leading position of *Journal of Cleaner Production* may be due to its broadness of scope, together with its high number of issues per year.

The identified SI comes from existing approaches, frameworks, strategies, methods, and tools for improving sustainability performance of products and firms in a wide perspective. Many of the information elements identified through the various approaches were overlapping, or described the same information issue but with other words. In such cases,

the sustainability information elements were reformulated and merged together for practical reasons. The first version of the sustainability information framework was based predominantly on sustainability information elements as they were described in scientific literature, and is presented as a sustainability information resource base (SIRB) in Part II: Results. The SIRB describes the stakeholder in question, it describes potentially useful information elements with a certain degree of accuracy, potential accessibility of sustainability information, the journal where the information element was identified, and finally, reference to the author(s) of the article. It is important to emphasize that the SIRB is based on this author's perception and interpretation of the reviewed material. Other reviewers of the material may draw other conclusions.

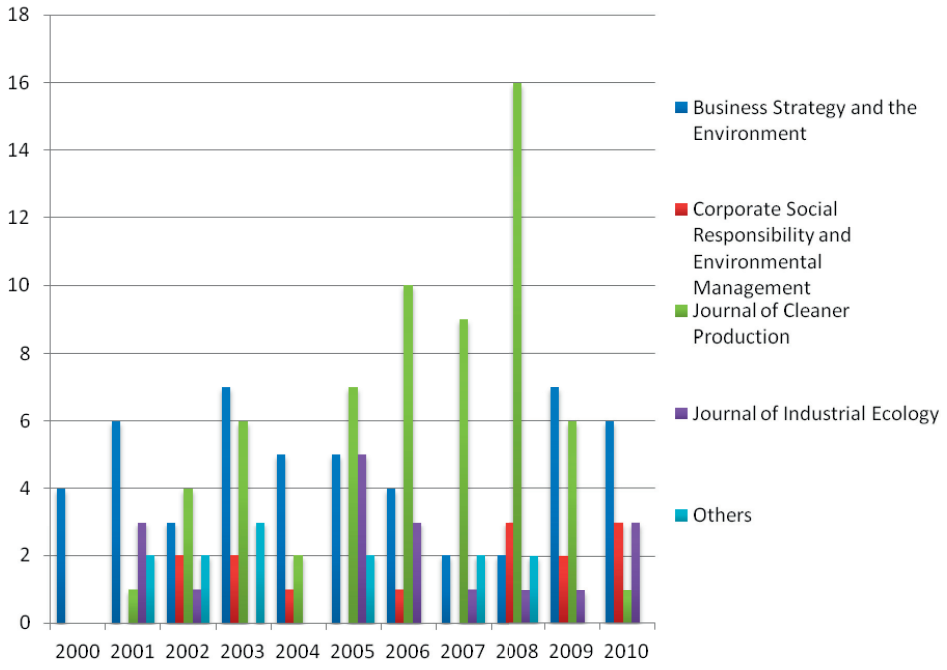


Figure 5-2: Publications by journal by year between 2000-2010

Phase 3: Reformulating and compiling sustainability information into a framework.

The initial idea was to develop a sustainability information framework based on a strict literature review. However, based on an evaluation of the gathered information from researched literature, the information elements were predominantly green, also in areas where information on social and ethical information elements could be just as interesting to consider. Hence, in order to develop a framework that was up to date with current development and industrial practice, information elements were reformulated where appropriate to also include the social and ethical aspects of sustainability. For instance, "export/import countries environmental regulations" was reformulated into "export/import countries sustainability regulations". Due to the reformulation of sustainability information elements, the final version of the framework as presented in Part II: Results, does not contain references to the original articles that inspired the sustainability information element description. Moreover, the descriptions of the information elements in this framework have been shortened, merged, simplified, and streamlined. This has been done to facilitate the use the framework, although there is a risk that the precision of the descriptions of the elements is reduced. However, in systems theory which this research is based on, high precision is not considered worth aiming for. Rather, the most important thing is what something can be used for (Arbnor and Bjerke 2009). It is therefore argued that the simplified version of the framework is better than the original SIRB, as the simplified framework is more approachable and considered easier to use in industrial practice as well as in research. A more thorough description of the novelty of the sustainability framework in terms of the scientific community, as well as its potential usefulness in industrial practice, is to be found in Article 2 (Aschehoug and Boks 2012b)

6. Introducing the case firms

The case firms were mainly chosen from firms participating in the SFI Norman project (three firms), but also two additional firms were selected in order to find representative cases. As described more in detail in Section B, representativity in a statistical sense is not valid in case studies based on systems view. Instead, the firms and cases are chosen to represent a certain type of system based on relevance to research questions, if the phenomenon to be studied may appear, and if it is feasible and ethical (Karlsson 2009). As some of the firms participating in the research requested confidentiality, the case firms were given fictitious names:

- HeatCom was chosen to represent a typical manufacturing firm in Norway. The firm is known to hold high environmental standards which were important to ensure that environmental concerns were integral parts of daily business. Having in-house product development, logistics, and sales departments was also important, so that in-house information flows were available for study. The firm was also targeted as it was big enough to have a complex stakeholder environment.

- AutoComA and AutoComB were chosen based on literal replication, e.g. both firms are Norwegian automotive suppliers and were predicted to have similar business contexts. Both firms are direct suppliers to original equipment manufacturers (OEM) in the automotive industry and have manufacturing plants and in-house product development departments.

- SitComA and SitComB were chosen based on theoretical replication. They both belong to the Norwegian furniture manufacturing industry. They have an entirely different business context than do the automotive suppliers. Moreover, they sell their products directly to end-customers. SitComA and SitComB both have manufacturing plants and in-house product development departments.

Table 6-1 on the following page summarizes key characteristics related to the case firms involved in this research project, including number of interviews and meetings.

Table 6-1: Main characteristics of case firms

	HeatCom	AutoComA	AutoComB	SitComA	SitComB
Main product	Confidential	Break couplings	Plastic fittings	Office chairs	Sofas and arm chairs
Number of employees	100	219	168	460	940
Turnover US$(million)[1]	US$82	US$433	US$36	US$165	US$430
Year of study	2009	2010	2010	2011	2011
Formal interviews	42	5	4	6	10
Formal meetings	5	2	3	2	2
Informal contacts	E-mail, telephones, brief encounters	E-mail, telephones, brief encounters	E-mail, telephones, brief encounters	E-mail, telephones, brief encounters	E-mail, telephones, brief encounters
Type of informants	-Product designers and engineers -Product development mng. -Purchasing mng. - Financial mng. -Firm stakeholders	-Product designers and engineers -Product development mng. -Purchasing mng.	-Product designers and engineers -Product development mng.	-Product designers and engineers -Product development mng. -Purchasing mng. - Environmental mng.	-Product designers and engineers -Product development mng. -Purchasing mng. - Environmental mng.

[1] Turnover figures in the table concerns the case firms, not the corporations' the firms belong to.

6.1 HeatCom

HeatCom is part of a corporation counting 4 firms with 6 manufacturing plants in three different countries, HeatCom being the largest in terms of sales and revenues. The corporation produces specialized composite products with reinforcement for the industrial and private market. In 2009 the corporation had approximately 300 employees and revenues of US$ 160 million. HeatCom has a supply base of twenty core suppliers in 10 different countries and manufactures products for the global marked. The production is fully automated, and annual production volume exceeded 1.2 million units in 2009. HeatCom does not produce for stock; hence production volumes are constantly adapted to sales. Their overall goal is to be world number one within its product segment. Reduced cycle time in production and increased efficiency are targeted improvement areas for reaching this goal.

HeatCom has two main product groups in different customer segments. More than 90% of the firm's revenues come from the product group used in the case study. This product is a specialized product which is mostly sold to network dealers who offer the product to end-customers dominantly through a product service system. The product is based on composite material and weighs almost 50% less than other similar products on the market. Main manufacturing processes include injection moulding from plastic resins and composite reinforcement.

Approximately 5-10% of annual revenues are spent on product development activities, either incremental improvements to existing products, or on new product development (NPD). Incremental improvements are typically driven by production problems, the wish to streamline a particular process in production, or the wish to enter a new market with an existing product. NPD activities are typically driven by strategic decisions to develop new product segments. Development projects are run equally for NPD and improvement projects, but development activities are limited to existing production technology platforms. All employees in HeatCom are encouraged to propose new ideas and development projects.

6.2 AutoComA

AutoComA is part of a large global corporation with 33 engineering and manufacturing facilitates in 20 countries worldwide. The corporation provides systems and solutions within the automotive, commercial vehicle, and industrial markets. The corporation employs approximately 10.000 people all over the world. In 2010, corporation revenues exceeded US$ 1300 million. The business areas are divided into automotive systems (60% of revenues), commercial vehicles systems (23% of revenues) and power products systems (17% of revenues). AutoComA lies within the segment of commercial vehicle systems and produces fluid transfer systems worldwide to medium and heavy commercial vehicles. Due to the world financial crisis, this business segment experienced sales drops from 20-90% in 2009 and was forced to reduce costs and number of employees. The development department, however, remained at nearly the same level in 2009 and 2010. Approximately 10 engineers and designers are part of the development department.

AutoComA predominantly produces brake couplings. Previously, these were mainly produced in brass. Today, couplings in composite material are the main product, which reduces the weight of the product considerably. 75,4 million couplings are produced annually at the manufacturing plant in Norway. The production is fully automated and constantly adapted to sales. Main manufacturing process includes fully automated

injection-moulding of composite material. Innovation and speed-to-market are significant areas of differentiation for AutoComA in the market.

Development activities may be incremental with a two-year perspective, or more radical like the change from brass to composite couplings. This development project started in 1995 and is still ongoing with new product variants introduced to the market regularly.

6.3 AutoComB

AutoComB is part of a corporation with 4 plants with engineering and manufacturing facilitates in 3 countries in Europe. The corporation is a leading supplier of engineered surface-treated interior and exterior plastic components to automotive car makers and employs approximately 800 people. Corporation revenues in 2010 exceeded US$ 260 million. Key competitive advantage is the in-house design and development department which reduces products' time to market. Within this corporation, AutoComB develops and produces bumper modules, trim mouldings, and spare parts. From the time an order is placed, the spare parts are produced and shipped within 48 hours.

Production at AutoComB is fully automated and includes injection-moulding and surface treated plastics. Injection moulding involves making parts from plastic resin. Plastic granulates are injected at high pressure into a mould or tool, which again gives the part the desired shape and characteristics. Surface treatment comprises several different processes to change the surface and appearance of the plastic part. The most important surface treatment process in AutoComB is painting. This process is a fully automated process with robots and conveyor systems.

Process-driven product development in partnership with customers is typical for AutoComB which does not develop or manufacture its own products. Approximately 43 engineers and designers are part of the development department. Product development typically consists of concept studies, component development, verification, materials selections, simulation, and testing and validations. Concepts and finalized products are verified in certified laboratories.

6.4 SitComA

SitComA is an international firm which develops and manufactures premium brand office chairs, conference furniture and cafeteria furniture for private and public office environments. Development and manufacturing activities are mainly located in Norway and Sweden. In addition, the firm has sales offices in five different countries in Europe.

Corporation revenues exceeded US$182 million in 2010. The main market is Scandinavia which accounts for 60% of the turnover. 35% of the remaining turnovers are created in the European marked. SitComA has approximately 460 employees. SitComA owns and develops three strong market brands, whereas the focus of the present research has been the Norwegian market brand, its development activities, and manufacturing plant. SitComA aims to become the leading office chair specialist in Europe through innovation combined with a people and nature oriented approach to product development.

SitComA has little traditional manufacturing at its Norwegian plant, the main process involves assembly of purchased parts. Great emphasis is therefore put on purchasing and supplier development in SitComA.

Research and development is top priority in the firm, both at brand and group level. In the development process, SitComA maintains close interaction with interior architects, professional dealers, ergonomic designers and buyers. SitComA has 23 employees working with product development and design for the Norwegian market brand in an inter-disciplinary group with competences like design management, modeling, upholstery, textile design, CAD, construction, environment & CSR, production, brand management, and project management. Several internal and external standards, in addition to computer aided-tools are used to guide the product development activities.

6.5 SitComB

SitComB is part of a corporation which develops and manufactures furniture in various locations in Norway, and is by far the largest furniture manufacturer in the Nordic region. This furniture is marketed all over the world by a network of national and regional sales companies. The product areas within the corporation are e.g. premium brand recliners, sofas, loveseats, and mattresses. SitComB employs approximately 1320 employees, and corporation revenues in 2010 exceeded US$ 520 mill. SitComB owns and develops three strong market brands, whereas the focus in the present research has been the two market brands which develop recliners, sofas, and loveseats. The corporation aims to be one of the world's most attractive suppliers of ergonomically designed furniture for the home.

SitComB manufactures approximately 90% of all parts needed for the furniture at its manufacturing plant in Norway, including block foam production, welding of steel parts, springs, production of wood parts, including varnishing and other surface treatment processes. Manufacturing of parts and furniture assembly are partly automated, but still many operations are carried out manually. Purchases are mainly limited to raw materials, covers (textiles and leather), and minor screws and fittings. Standardized components and

designs have been keys to satisfy both market requirements and the need for efficient production.

Product development is a prioritized area within SitComB, in which emphasis is given to the design and development of product concepts which provide functionality and comfort to end-customers. The development department employs approximately 24 inter-disciplinary developers, with different competence equal to that of SitComA. Several internal and external standards, in addition to computer aided-tools are used to guide the product development activities. Environmental considerations are an increasingly important part of the product development department's work.

7. Summary of appended articles

This thesis is mainly based on the results described in the five appended articles. The relationship between the research questions and the article contents is illustrated in Figure 1-1 (Lundteigen 2009:9). The purpose of this section is to clearly state the purpose of each article, to shortly present the results and conclusions, and to clearly describe the contribution of the article to this thesis.

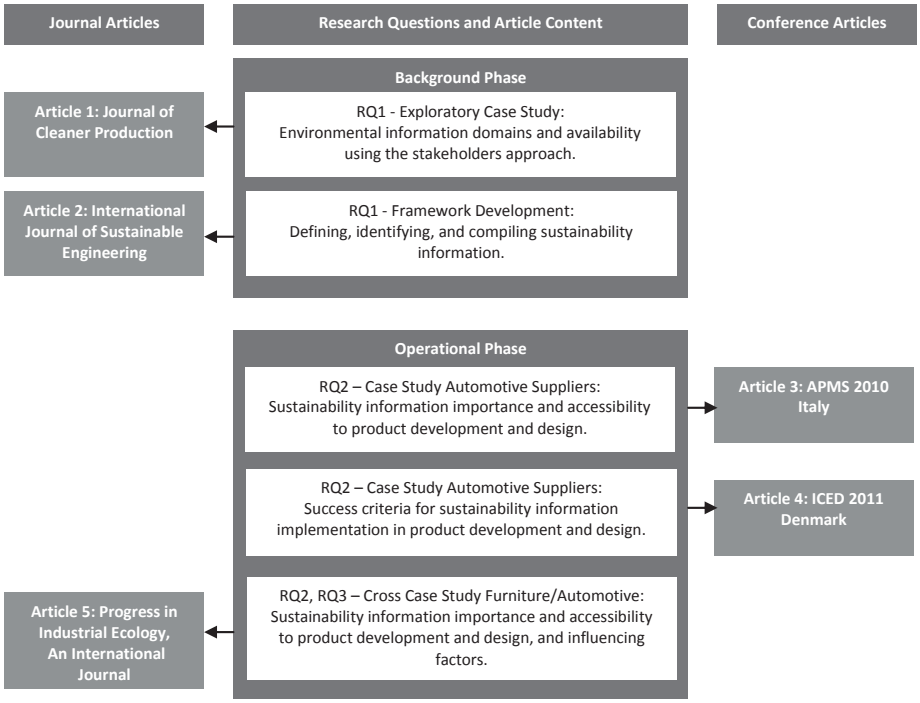


Figure 1-1: The relationship between research questions and articles produced

In addition, two more articles were written during the present research project and presented in international conferences as full paper presentations. These are "A framework for identification of environmental information among stakeholders", presented at

EcoDesign 2009 in Tokyo (Aschehoug et al. 2009), and "Investigating the importance of sustainability information in product development and design" which has recently been submitted to NordDesign 2012. These two articles have not been included in the article collection as their academic contribution in addition to those articles included here are less significant.

7.1 Article 1: Environmental information from stakeholders supporting product development

Aschehoug, S., C. Boks, and S. Støren. 2012. Environmental Information from Stakeholders Supporting Product Development. Journal of Cleaner Production **31**:1-13, (Aschehoug et al. 2012).

Purpose

Environmental information beyond product and process data is a prerequisite for making knowledge-based decisions in product development and design and for developing products with lower environmental impacts. The article's main purpose was twofold; 1) to investigate if the stakeholder approach for indentifying, collecting, and compiling environmental information relevant to product development and design was viable, and 2) to explore what kind of environmental information and expectations were available from external stakeholders, and to which extent internal stakeholders in a firm know about this information. This first article builds and elaborates on findings from the article Aschehoug et al. (Aschehoug et al. 2009), in which all focus was on internal stakeholders.

Research approach

The article provides a brief introduction to the concepts of data, information, and knowledge as well as the motivation for using stakeholder theory as an approach for identifying and collecting relevant environmental information and expectations to product development and design. Stakeholders can for instance be approached directly to identify true insights, as done in this case study. A perhaps more viable long term approach for indentifying environmental information and expectations is to involve external stakeholders more directly in firm business processes.

A single case study was conducted within the Norwegian manufacturing industry with an in-house product development department. A single case study was chosen to provide sufficient depth and understanding of the research area. Semi-structured interviews were carried out with 12 individuals within the case firm in which the focus was on in-house environmental information and expectations knowledge concerning one product segment within the case firm, but also in-house information and expectations towards the firm itself. These results where then compared to 30 interviews with external stakeholders on the same matter.

Main results

The interviews yielded valuable results supporting the stakeholder approach for identification and collection of environmental information and expectations relevant to product development and design. The results from the interviews further indicated a substantial gap between information availability, "what's out there", and firm knowledge on the same matter. For example, internal stakeholders in the case firm were unknowledgeable about the fact that important external stakeholders like consumers (end customers) expressed that they would choose the most environmentally friendly product at equal price if the environmental attributes of the product were easily displayed, for example as an inherent property of the product. The potential usefulness of such environmental information is envisioned in the early phases of product development and design, for generating design specifications and requirements, or for developing alternative product solutions in concept development. The case firms current strategy and technology supports inclusion on such information in product development and design.

Research academic contributions

- Convincing examples of environmental information and expectations from a Norwegian manufacturing firm potentially relevant to product development are presented. Both firm level information and product level information and expectations are presented as well as the stakeholders involved (information source).
- The observed gap between environmental information availability from external stakeholders and environmental information perception and knowledge in the case firm suggests a need for systematic identification, collection, and compilation of environmental information and expectations in a product development and design context. Such information may increase firm knowledge on environmental issues and ability to develop more environmental friendly products, and thereby enhance firm competitiveness by adding value to products beyond functionality, quality, and cost.
- The gap between availability and knowledge on environmental information and expectations among internal stakeholders indicates a need for further studies on such information flows.
- Cultural framing was observed both with respect to information source (stakeholder importance) and information receiver (department, function). Professional training for instance, was observed to influence what types of information that internal stakeholders searched for.

Research industry contributions

- A systematic compilation of environmental information and expectations from all firm stakeholders which may be used by the case firm to build knowledge and to increase the firm's ability to develop more environmental friendly products.
- Practical "proof" of the limited use of such information in product development today, and hence corresponding improvement possibilities available to the firm.
- Although not scientifically measured before and after the interviews, the researcher observed increased environmental awareness and knowledge among the interviewees concerning the importance of addressing product environmental attributes in addition to manufacturing and production environmental concerns.
- The case study work itself maintained or created a positive impression of the firm among the external stakeholders interviewed.

7.2 Article 2: Towards a framework for sustainability information in product development and design

Aschehoug, S. H. and C. Boks. 2012. Towards a framework for sustainability information in product development. International Journal of Sustainable Engineering:1-15 (Aschehoug and Boks 2012b).

Purpose

The third article describes the theoretical and practical development of a sustainability information framework for use in sustainable product development and design. The aim has been to demonstrate the value of using more and other types of information in sustainable product development than is done through the current scope of existing tools and methodologies, and to provide a framework which renders possible further studies on sustainability information in industrial practice.

Research approach

The article synthesizes existing literature from the period 2000-2010 with the purpose of identifying, collecting, and compiling relevant sustainability information into a framework for sustainability information. The justifications for the sustainability information framework is the initial case study in which a large gap was observed between information availability from external stakeholders and corresponding information knowledge within a firm.

Results

The article introduces a definition of sustainability information relevant to sustainable product development and design. Identified, collected, and compiled, the article also presents the sustainability information framework by stakeholder group. The framework presents key information elements potentially relevant to sustainable product development in the manufacturing industry, independent of firm size. The information elements are organized based on their most prominent product life cycle phase, as information on sustainability impacts across all stages are equally important to sustainable product development. A review of how sustainability information relates to each stakeholder group is also given in the article. The framework is envisioned used for creating knowledge and general decision support in product development and design, or for inspiring the generation of new meaning to products.

Research academic contributions

- A definition of sustainability information - and its aim and use.
- A comprehensive sustainability information framework for product development and designed is outlined.
- The contribution of the framework is the combination of the following elements: 1) the focus is shifted from supply chain or value chain perspective, in which only a limited number of stakeholders are considered, towards a holistic stakeholder approach which includes all relevant firm stakeholders, 2) the framework incorporates information on sustainability issues, not only environmental information, 3) the focus is expanded from product and process data to information beyond such data, which opens up for the consideration of more information elements in product development than before, and 4) information specifically targeted product development and design has been identified and compiled.
- This framework renders further studies on sustainability information possible in industrial practice.

Research industry contributions

- The industrial usefulness of the complete sustainability information framework provides firms with an overview of information that may be relevant to product development and design and where it may be found.

7.3 Article 3: Sustainability information in product development – the case of the automotive supplier industry

Aschehoug, S. and C. Boks. 2010. Sustainability Information in Product Development - the Case of Automotive Supplier Industry. APMS 2010, Internation Conferance on Advances in Production Management Systems, Cernobbio, Italy (Aschehoug and Boks 2010).

Purpose

The article outlines the theoretical development of the first version of the sustainability information framework, the so-called sustainability information resource base (SIRB) as presented in Section 16. The article's main purpose was to investigate if it was possible to develop an industry specific SIRB by using information quality criteria to assess which sustainability information was most important and accessible to product development and design (as viewed by product developers) in the context of the Norwegian automotive supplier industry.

Research approach

Two case studies were conducted within the Norwegian automotive supplier industry with in-house product development departments. Semi-structured interviews were carried out with five individuals within AutoComA and three individuals from AutoComB. During the interviews, information elements considered useful to product development and design were first identified, before an assessment was made whether these information elements were of high importance (i.e. can the information element potentially build knowledge and does it concern sustainability issues relevant to the firm) or low importance to product development and design. Finally, an assessment was made of information accessibility based on operational experience.

Main results

The article presents the accumulated results from the analysis of the interviews conducted in AutoComA and AutoComB. All sustainability information elements ranked with high importance to product development and design from both firms are consequently reported.

All in all, the firms demonstrated many similarities in the way they ranked information importance and accessibility. The results yield what appears to be a typical automotive supplier industry behavior with high focus on requirements, from the government in the form of regulations, customer requirements, or information concerning requirements for various sustainability certificates. The corresponding low focus on NGOs' and media's

sustainability information elements may be explained by AutoComA and AutoComB's position in the supply chain, as the firms are suppliers and consequently not the focal firm in a value chain. Another finding from the studies was that the interviewees pointed out that they expected sustainability information to be most effective or influential in new product development as the degree of freedom in design is greater in new product development than in redesign. Moreover, the use of multi-disciplinary teams in development projects is expected to facilitate internal sustainability information flow in firms and increase the accessibility of such information.

Research academic contributions

- The most important sustainability information from two firms in the Norwegian automotive supplier industry has been identified and singled out in a customized sustainability information framework. This result is the first attempt to build knowledge on sustainability information importance in product development and design, and may consequently be the starting point for further research on this issue.
- Information from stakeholder groups like media, owners and investors, banks and financial institutions was not considered important to product development and design. Instead, sustainability information from these stakeholder groups was considered important to management and in influencing overall firm reputation.
- Multi disciplinary development projects with various functions as product design, material specialists, marketing and sales, purchasing, and manufacturing was reported as important for making sustainability information more accessible to product development and design.

Research industry contributions

- The most important sustainability information for two firms in the Norwegian automotive supplier industry has been identified and singled out in a customized sustainability information framework. Collecting these information elements in "real life" from relevant stakeholders may contribute to learning and increased knowledge on sustainability issues, and hence increase the firms' ability to develop more sustainable products.
- Although not scientifically measured before and after the interviews, the researcher observed increased sustainability awareness and knowledge among the interviewees in both firms based on the interviews conducted compared to the following feed-back session.

7.4 Article 4: Success criteria for implementing sustainability information in product development

Aschehoug, S. and C. Boks. 2011. Success criteria for implementing sustainability information in product development. ICED 11, 18th International Conference on Engineering Design. the Design Society, Copenhagen, Denmark (Aschehoug and Boks 2011).

Purpose

The fourth article builds directly on the results of article number three. The main purpose of the fourth article was to investigate how important information in the customized sustainability information framework from AutoComA and AutoComB can be implemented most efficiently in these firms. Implementation in this article was used as the process and activities necessary for the realization of sustainability information in product development and design, or more precisely, what firms need to do to facilitate the "use" information elements in their day to day activities. Use is in this context further denoted as the process firms apply to gather and interpret information, or build knowledge based on such information.

Research approach

The research builds on a case study, with one group creativity session with product designers from the automotive supplier industry, AutoComA and AutoComB. An additional two interviews were also conducted to verify the results found during the creativity session. The brainwriting 6-3-5 method was applied during the workshop, meaning 6 people writing down 3 ideas in 5 minutes and then passing the sheet along until everyone has written 3 ideas on all 6 sheets.

Results

A brief overview of scientifically described pros and cons concerning brainstorming and brainwriting was provided, mainly from the field of psychology. The following brainwriting session generated 111 generated ideas, 79 of these were found to be unique. These ideas for successful implementation and use of sustainability information were compiled into nine categories based on induction. The main categories were: 1) management commitment, 2) linkage to economic performance and shareholder value within the firm 3) stricter requirements from public authorities, 4) academia as a knowledge provider or knowledge broker, 5) customer demands and requirements, 6) establishment of an in-house task force, 7) establishment of an industrial cluster task force, 8) integration

into existing procedures and work processes, and 9) build internal competence on sustainability issues.

Research academic contributions

- Success criteria for the implementation and use of sustainability information in two automotive supplier firms have been developed and proposed, although the criteria's effectiveness and success have not been tested.
- The results may also have relevance to other firms in the automotive supplier industry, and possibly in other industries. The results may be used to study implementation processes in other firms, or to compare the criteria to the implementation of other aspects of sustainability issues.

Research industry contributions

- Success criteria for the implementation and use of sustainability information in product development and design relevant to their firms and industry. Non-relevant criteria were sorted out during the analysis phase.
- The benefit of "learning by doing" a new creativity method for generating ideas to complement the commonly used brainstorming method in these firms. Thorough instructions on the new method, in addition to pros and cons concerning brainwriting and brainstorming were given to the participants.
- Although not scientifically measured before and after the brainwriting session, the researcher observed an increased sustainability awareness and knowledge among the participants in both firms based on discussions after the brainwriting session.

7.5 Article 5: Building sustainability knowledge for product development and design – Experiences from four manufacturing firms

Aschehoug, S. and C. Boks. 2012a. Building sustainability knowledge for product development and design - Experiences from four manufacturing firms. Submitted to Progress in Industrial Ecology, An International Journal (Aschehoug and Boks 2012a).

Purpose

This article's main purpose is to investigate what sustainability information relevant to product development and design is considered important and accessible in manufacturing firms (as viewed by product developers) and to explore what factors influence perceived importance and accessibility of such information in manufacturing firms. The article is a cross case analysis between the automotive supplier firms presented in articles 3 and 4, and two Norwegian furniture manufacturing firms, SitComA and SitComB.

Research approach

Four case studies were conducted in Norwegian manufacturing industry. The firms all have in-house product development departments and manufacturing plants in Norway and are known for high environmental standards and interest in sustainability issues. Semi-structured interviews were carried out with six individuals within SitComA, with ten individuals from SitComB, and then compared to the results from five interviews conducted in AutoCom A and three interviews in AutoComB. The sustainability information framework was used as an interview guide and a starting point for discussions on the different sustainability information elements. Information elements considered useful to product development and design were first identified. Then an assessment was made whether these information elements were of high importance or low importance to product development and design (i.e. if the information elements could potentially build knowledge and if they concerned sustainability issues relevant to the firm). Finally, an assessment was made of information accessibility based on the interviewees' operational experience.

Main results

The article presents the accumulated results by industry sector, i.e. the automotive supplier industry and the furniture industry. Sustainability information ranked with high importance to product development and design from both industry sectors is reported. Main similarities and differences between the two industries are discussed. Suggested use of sustainability information in product development and design is also been outlined in the article.

The industry sectors demonstrated consensus concerning sustainability information importance from the stakeholder groups of academia, industry associations, and customers. More diverging results emerged concerning the stakeholder groups of government, NGOs, media, shareholders, financial institutions, suppliers, and customers. When it comes to sustainability information accessibility, the most significant differences identified were related to the stakeholder groups of industry associations, suppliers, and customers.

Factors suggested influencing perceived sustainability information importance in the case firms are business strategies and goals, sustainability leader vs. sustainability follower, sustainability knowledge and awareness, adherence to voluntary sustainability standards, previous positive experience with sustainability information use, business contexts, customer types, and supply chain position.

Research indicates that factors influencing perceived accessibility of sustainability information may be type of information generating activities the firms are involved in, customer types, relative strength of supplier and firm, organization of inter-disciplinary teams in product development and design, as well as organization of HSE functions in relation to product development and design.

Research academic contributions

- The most important sustainability information relevant to product development and design in four firms in Norwegian manufacturing industry has been identified and presented by industry sector in two customized sustainability information frameworks. Collecting these information elements in "real life" from relevant stakeholders may contribute to learning and increased knowledge on sustainability issues in these firms, and hence increase their ability to develop more sustainable products.
- Factors believed to influence perceived sustainability information importance and accessibility in these four firms are proposed, and this article thus adds to the limited body of literature concerning organizational and soft aspects of sustainable product development and design.
- The wide variety of factors influencing importance rating indicates that sustainability information frameworks as presented for the furniture and automotive supplier industry respectively should be customized in line with current priorities in each firm or industry.
- These results are an attempt at building knowledge on sustainability information importance in product development and design and may consequently be the starting point of further research on this issue in other firms and in other industries.

Research industry contributions

- The most important sustainability information relevant to product development and design in four firms in Norwegian manufacturing industry has been identified and presented by industry sector in two customized sustainability information frameworks. Collecting these information elements in "real life" from relevant stakeholders may contribute to learning and increased knowledge on sustainability issues in these firms, and hence increase their ability to develop more sustainable products.
- Possessing more knowledge of the factors believed to influence perceived importance and accessibility of sustainability information, the case firms may use this knowledge to actively change and improve current processes and performance by implementing measures that directly affect these factors on firm level.
- Although not scientifically measured before and after the interviews, the researcher observed increased sustainability awareness and knowledge among the interviewees in both firms based on the interviews conducted compared to the ensuing feed-back session.

8. Reflections

This PhD thesis presents the results from a research project of three years' duration. The starting point of this project was mainly to investigate what sustainability information potentially relevant to product development and design was beyond the traditional aspects of product and process data, how this "commodity" could be identified, where it could be collected, and how it could be compiled.

An important motivation for taking on this research was to help firms in their attempts and ongoing work to develop more sustainable products. The assumption was that sustainability may be one way of adding value to products beyond functionality, quality, and cost, and thus increase firms' competitiveness. Such help may be introduced to firms in various ways. In this thesis, the path of identifying, collecting, and compiling sustainability information that may contribute to knowledge was chosen. In product development and design, extensive amounts of information are used. It is therefore important to single out sustainability information elements that may be truly useful to build knowledge. The sustainability information framework has been developed as the result of this work. This framework was mainly developed based on other researchers' work, but has also been updated and modified based on this researcher's knowledge gained during the progress of this work. Once customized suitably to firms, it is this researcher's hope that when firms collect these information elements in real life, the information elements themselves, but also the process of collecting the information, will contribute to increased knowledge on sustainability issues. Increased sustainability knowledge in product development and design may be a key to increasing firms' ability and opportunity to develop and manufacture more sustainable products.

Once a sustainability information framework was established to study sustainability information in sustainable product development and design, case studies in four different firms were conducted. Central elements in the case studies were product developers' and designers' views on information importance and accessibility, based on information quality criteria. The results presented should be regarded as indicative only, as the data collected in the case studies reflect the personal opinions of the firms' employees. The employees participating in the case studies as presented in Table 6-1, are mainly concerned with operational product development and design tasks. Therefore, their answers reflect their view of the world. Other employees at corporate or management level may have responded differently to the questions, as they are inclined to be more concerned with long-term strategic issues. The differences in answers given by product development managers and product designers indicate such a difference in world view. However, as the overall aim of

the present research was to identify information elements that may contribute to knowledge on sustainability issues in product development and design, not in the firm as a whole, that difference is not regarded as problematic.

An important precondition for the present work is the definitions on information and knowledge used in this thesis. Rather than discussing information use, the term knowledge is used. Once a product designer starts using and exploiting information and turning this into practice, the information has been received and interpreted by the information user, based on the users' beliefs, values, and so on. As Nonaka describes it, information is a flow of messages, while knowledge is created and organized by this information flow founded in the commitment and beliefs of the holder (Nonaka 1994). Knowledge has also been described as the ability of the individual to understand information, including how it is then handled, applied, and used in a situation (Court 1995). In this respect, the information elements may only contribute to the development of more sustainable products when the product designers use this knowledge for various purposes in product development and design.

Perceived importance of different sustainability information elements as presented in this research project is a dynamic entity. It is an entity that depends on different influencing factors, both inside the firms themselves and within the specific industry as indicated in this thesis. Given that sustainability is such a broad and un-tangible term, it is this researcher's opinion that sustainability information importance also is inclined to reflect values and trends in society concerning sustainability. This interdependency of many factors in a system is a typical characteristic of systems theory on which systems view is grounded as presented in the *totality* principle in Section 3.1. The current financial crisis in Europe, for instance, may make the economic aspects of sustainability more dominant, or on the contrary, make other values in society like frugality, sharing of products, and function more salient. Climate changes and how these will affect us is another important and possibly influencing factor which may affect societal values. Extreme weather, drought, and famine may make people in general more open to discussing issues like sustainable employment in development countries, or issues like negative population shifts as an effect of purchasing raw materials from developing countries. Moreover, some of the current markets like Europe are beginning to reach a level of saturation for manufacturing goods. Will this saturation lead to an enormous growth in the BRIC (Brazil, Russia, India, China) countries, or will the saturation lead to a societal change and make us look to other ways of fulfilling and satisfying our individual needs than today? All these issues are inclined to affect and change societal values in one direction or another, and lead to a corresponding change in the way sustainability issues in general are perceived, and also the way sustainability

information importance is perceived on firm level in relation to sustainable product development and design. How fast the meaning and implications of the notion of sustainability will change is difficult to predict, all we know is that they will change. This change refers to another typical characteristic of systems theory, the *unpredictability* principle which states that due to the continuous interaction of a system with the surrounding environment, there will be a limit to predicting its future.

An important lesson was learned when approaching the different firms with the sustainability information framework. An attempt was made to have the interviewees differentiate between sustainability information importance today, and sustainability information importance in the future. This approach was, however, abandoned in every interview, as the informants found it impossible to differentiate between the two. Frequently mentioned arguments against such differentiation concerned the impossible task of predicting the future as such, or of predicting what the firms might prioritize in the future. As a consequence, the sustainability information importance is predominantly based on *today's* perception of sustainability information importance.

An issue of particular interest to this researcher was the way firms responded to the research process during the various phases of interviews, feed-back sessions, and discussions. Approaching the firms, the researcher also became a stakeholder and an "information domain" like the other stakeholder groups reviewed in this project. Without exception, an increased understanding and knowledge of sustainability issues in general was observed throughout the project in all participating firms. During the first interaction with the case firms, the term sustainability was often interpreted as being equal to environmental. After the interviews and the following clarifying meetings, however, the interviewees had gained a more holistic understanding. Even in the most developed firm, concerning sustainability issues, participating in the research project (SitComA), several of the product designers were surprised to learn about all the different information elements and how broad the sustainability concept actually is. Bearing this in mind, the research project has been important to the participating firms by contributing to increased sustainability awareness and knowledge. As one of the interviewees commented during a feed-back meeting: "*You being here discussing sustainability information issues has been more effective for the sustainability awareness in our organization (product development) than what we could have accomplished ourselves through several months of work"*.

9. Conclusions and contributions

Today, firms are increasingly faced with pressures from stakeholder groups to improve their overall sustainability performance. Consequences of industrial activities and unsustainable consumption are becoming more and more apparent in the social, environmental, and economic systems. The question is no longer whether firms should consider the sustainability impacts their activities have, but rather how to integrate such sustainability issues in day-to-day decisions, actions, and strategic priorities (Epstein 2008). This PhD thesis is an attempt at addressing this challenge by identifying, collecting, and compiling sustainability information relevant to product development and design that may contribute to building knowledge on sustainability issues. Increased knowledge and awareness on sustainability issues may further enhance firms' opportunity and ability to develop and manufacture more sustainable products. Such sustainable products may be one way of adding value to products beyond the traditional aspects of functionality, quality, and cost, and thus increase firms' competitiveness.

The five appended articles are an attempt at contributing to this sustainability challenge firms are faced with. More specifically, the overall contributions of thesis are based on the research questions presented in Section 1.2:

RQ1: How can sustainability information relevant to product development and design be identified, collected, and compiled?

Article 1 addresses this question by exploring what the environmental aspects of sustainability information are, and what types of environmental information is available "out there" in the real world. The article further explores if the stakeholder approach is a viable path for identifying, collecting, and compiling such information in an organized and efficient manner. Main conclusions demonstrates that there is product and design relevant environmental information available among firm stakeholders, information which potentially could affect decisions and design choices, and which currently to a large extent is unexploited by the case firm. Specific and concrete examples of environmental information are given in the article. In addition, the stakeholder approach proved viable for collecting information in industrial practice and for compiling and presenting this information.

Article 2 addresses research question one more academically by identifying, collecting, and compiling all types of potentially relevant sustainability information from extant scientific literature. This resulting SIRB presented in Section 16 contains the information elements

with literature reference. The final sustainability information framework presented in Article 2 has been simplified, streamlined, and updated based on knowledge generated through the case studies. This new framework may be used for further studies by other researchers, but the main intent is that this new framework can be customized by firms. Once customized by firms, collecting these information elements in real life from relevant stakeholders may contribute to learning and increased knowledge on sustainability issues in the firms. This may further enhance firms' ability to develop more sustainable products.

RQ2: What sustainability information relevant to product development and design is considered important and accessible to Norwegian manufacturing firms?

Article 3 and 5 address this research question in terms of importance and accessibility based on product developers' view of the matter. Accumulated results in terms of customized sustainability information frameworks are presented. Article 3 presents the information framework from two case firms in the Norwegian automotive supplier industry. Article 5 presents the information framework from two case firms in the Norwegian furniture industry, as well as the results from Article 3. The two industry sectors demonstrated consensus concerning sustainability importance from the stakeholder groups of academia, industry associations, and customers. The results varied more for the stakeholder groups of government, NGOs, media, shareholders, financial institutions, suppliers, and customers. Differences in importance and accessibility rating between the industries and firms are discussed and presented in order to further understand what influences and shapes these differences. This last part is mainly a contribution to the third research question:

RQ3: What are the key variables and factors which influence perceived importance and accessibility of sustainability information in Norwegian manufacturing firms?

Article 5 presents the factors that are believed to influence the importance and accessibility of sustainability information. Factors suggested influencing importance in the case firms from the Norwegian automotive supplier and furniture industry are: business strategies and goals, sustainability leader vs. sustainability follower, sustainability knowledge and awareness, sustainability standards adherence, previous positive experience with sustainability information use, business context, customer type, as well as supply chain position. Factors suggested influencing accessibility are: type of information generating activities the firms are involved in, customer types, relative strength of supplier and firm, organization of inter-disciplinary teams, and organization of HSE functions. The wide variety of factors influencing perceived importance and accessibility indicates that

sustainability information frameworks must be suitably customized to firms or industries in line with current situations and demands in firms or industries. The approach of "one size fits all" does not apply.

Article 3 presents a work based on a group creativity session with product designers in the automotive supplier industry. An attempt was also made to understand and identify success factors for the implementation of a customized sustainability information framework. 79 unique ideas were identified by the group participants, 60 of these ideas being both feasible and relevant for implementation. The ideas generated include traditional implementation issues such as management commitment, linkage to economic performance and shareholder value, customer or regulatory demands and requirements, integration into existing internal procedures and work processes, as well as sufficient internal competence on sustainability issues. More novel ideas include the development of a task force for sustainable information and knowledge exchange within the industrial cluster the designers belong to, or an in-firm task force for the same purpose. Increased collaboration with academia was also emphasized as important for the successful implementation of sustainability information in firms. Many of the success factors identified through the study are linked to sustainability knowledge and competence in organizations. This, then, has been a major reason for developing the sustainability information framework of this thesis.

Implementing the sustainability information framework in industrial practice has not been the prime target of this thesis. However, based on the "design paradox" presented in Section 4.1, it is argued that this sustainability information may be most effective for generating knowledge in the initial phases of product development and design. Even so, the knowledge generated through sustainability information may be used in all product development and design phases. Envisioning a generic development process as described by Ulrich and Eppinger (Ulrich and Eppinger 2008), sustainability information may be used in the *planning phase* in developing detailed product requirements and specifications, in developing proposals and a broad range of product scheme solutions in the *conceptual phase*, and in choosing between different product schemes in *system level design*, as well as in supporting decision making in the later phases of product development.

Another intriguing area of sustainability information application is envisioned when such information is used to build knowledge on future scenarios. Sustainability knowledge on related to future trends and evolutions may inspire firms to propose entirely new meanings to products through sustainability. It has been argued by others that such radical innovation of product meanings are rarely pulled by users, but are rather proposed by firms through design driven innovation by manufacturers' knowledge on future socio-cultural evaluations

(Verganti 2009). Hence, firms' interaction with various stakeholders to gather sustainability information may generate knowledge that may inspire such new product meanings.

Developing sustainable products is considered more a journey, than a destination. Thus the competent use of sustainability information as identified in this thesis, in order to build knowledge in product development and design, may be one step on this journey.

10 Further work

A research path not followed by this project, which potentially could be interesting, is to study sustainability information use in connection with other processes in industrial practice. For instance, marketing and sales are usually involved in defining market segments, identifying customer needs, and in the communication between a firm and its customers (Andreasen and Hein 1986, Ulrich and Eppinger 2008). The developed framework may be used to investigate which sustainability information elements from the customer domain are important and accessible to marketing and sales. Correspondingly, the framework may be used to investigate which sustainability information elements are considered most important and accessible at management level. One could also envision information elements important to firms' brands and reputation to be more important on management level.

Another potentially interesting research path could be using the sustainability information framework to map which types of sustainability information are already in use in firms, and which information is not. Is there for example a "formula" for best integration practice in firms? Or do firms that use a lot of sustainability information have products with better sustainable attributes? These and many more questions may be studied while using the sustainability information framework as a reference.

An important issue that can be pursued in research is the quality of the information elements described in the framework. Is it difficult for firms to get information of the right quality? Is the information from all stakeholders trustworthy, or are some information domains (stakeholders) likely to doctor the information they convey to look their best? And how do firms deal with sustainability information quality issues on firm level?

Research into the IT-system part of sustainability information use and exchange is yet another issue that may be pursued. Several approaches for IT-systems on information and knowledge already exist, but can they be used efficiently for this type of information exchange between a firm and its stakeholders? Are PLM (product life management) systems suitable to handle this task? Or is it most efficient to handle the information exchange through simply fashioned checklists and Excel spreadsheets for identification and collection of such information?

If more research was carried out in line with the described propositions, the general body of knowledge concerning sustainability information in firms would increase. Such knowledge may be used by firm for streamlining their information processes to maximize the utility value for all processes, not only product development and design, while minimizing the input effort.

Part II: Results - The sustainability information frameworks

11. Results – The Sustainability Information Resource Base (SIRB)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Government	Mandatory requirements under REACh (the firm that market the chemical)	REACh EC Directive	Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Journal of Cleaner Production Journal of Industrial Ecology Journal of Environmental Management	Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Koch and Ashford 2006 (Koch and Ashford 2006) Subramanian et al. 2010 (Subramanian et al. 2010) Fuhr and Bizer 2007 (Führ and Bizer 2007) Ny et al. 2008 (Ny et al. 2008) Angerer et al. 2008 (Angerer et al. 2008)
	Mandatory EcoDesign requirements for energy using products (EuP)	EuP EC Directive	Journal of Industrial Ecology Journal of Cleaner Production	Tukker et al. 2006 (Tukker 2006) Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009)
	Mandatory requirements under Restriction of the Use of Certain Hazardous Substances in Electrical Equipment (RoHS) Directive	RoHS EC Directive	Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Business Strategy and the Environment Journal of Cleaner Production Journal of Cleaner Production	Subramanian et al. 2010 (Subramanian et al. 2010) Tukker et al. 2006 (Tukker 2006) Ny et al. 2008 (Ny et al. 2008) Rock et al. 2006 (Rock et al. 2006) Wilson et al. 2010 (Wilson et al. 2010) Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Gehin et al. 2008(Gehin et al. 2008)
	Mandatory requirements under the End-of-Life Vehicle (ELV) Directive.	ELV EC Directive	Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Corporate Environmental Strategy	Subramanian et al. 2010 (Subramanian et al. 2010) Tukker et al. 2006 (Tukker 2006) Ferrao et al. 2006 (Ferrão et al. 2006) Wells and Orsato (Wells and Orsato 2005) Gerrard and Kandlikar 2007 (Gerrard and Kandlikar 2007) Forslind 2009 (Forslind 2009) Gehin et al. 2008(Gehin et al. 2008) Wilson et al. 2010 (Wilson et al. 2010) Honkasalo 2001(Honkasalo 2001)
	Mandatory requirements under the Wastes from Electrical and Electronic Equipment (WEEE directive)	WEEE EC Directive	Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production	Wilson et al. 2010 (Wilson et al. 2010) Seuring 2004 (Seuring 2004a) Subramanian et al. 2010 (Subramanian et al. 2010) Tukker et al. 2006 (Tukker 2006) Ny et al. 2008 (Ny et al. 2008) Rock et al. 2006 (Rock et al. 2006) Gerrard and Kandlikar 2007 (Gerrard and Kandlikar 2007) Forslind 2009 (Forslind 2009) Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Government			Journal of Cleaner Production	Gehin et al. 2008(Gehin et al. 2008)
	Mandatory requirements under Packaging and Packaging Waste	Packaging Waste EC Directive	Business Strategy and the Environment Journal of Cleaner Production Journal of Cleaner Production	Wilson et al. 2010 (Wilson et al. 2010) Forslind 2009 (Forslind 2009) Gehin et al. 2008(Gehin et al. 2008)
	Extended producer responsibilities (EPR), including take-back or EOL handling obligations for producer	National EPR requirements	Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Li and Geiser 2005 (Li and Geiser 2005) Wilson et al. 2010 (Wilson et al. 2010) Forslind 2009 (Forslind 2009)
	Integrated Product Policy (IPP)	IPP EC Green Paper	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Ecological Economics Corporate Environmental Strategy	Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Sundkvist and Finnveden 2007 (Sundkvist and Finnveden 2007) Li and Geiser 2005 (Li and Geiser 2005) Subramanian et al. 2010 (Subramanian et al. 2010) Tukker et al. 2006 (Tukker 2006) Rosen et al. 2002 (Rosen et al. 2002) Sanne 2002 (Sanne 2002) Honkasalo 2001(Honkasalo 2001)
	National guidelines and priorities within Integrated Pollution Prevention and Control (IPPC)	National Governments	Journal of Cleaner Production	Geldermann and Rentz 2004 (Geldermann and Rentz 2004)
	Purchasing guidelines and requirements for environmentally responsible public procurement	Governmental and institutional purchase guidelines. Invitation to submit tenders, etc.	Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology	Li and Geiser 2005 (Li and Geiser 2005) Rubik and Scholl 2002 (Rubik and Scholl 2002) Del Río et al. 2010 (Del Río et al. 2010)
	Export/import countries environmental regulations	National Governments	Journal of Cleaner Production	Zhu et al. 2007 (Zhu et al. 2007)
	Proactive actions to pre-regulations (new regulations)	National Government EU Government	Journal of Cleaner Production	Walker et al. 2008 (Walker et al. 2008)
	Governmental campaigns targeted at raising sustainable awareness and changing consumer behavior	National Government	Journal of Cleaner Production	Mont and Plepys 2008 (Mont and Plepys 2008)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
NGOs	Documentaries and campaigns targeted at specific products, substances, firms, practices (i.e. uncovering inhuman working conditions, child labor), or industries (negative information)	TV, newspapers, magazines, and internet observations and monitoring	Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Strategic Management Journal European Management Journal	Waygood and Whrmeyer 2003 (Waygood and Wehrmeyer 2003) de Boer 2003 (de Boer 2003) Huijstee and Glasbergen 2008 (van Huijstee and Glasbergen 2008) Cramer 2002 (Cramer 2002) O'Rourke 2005 (O'Rourke 2005) Erlandsson and Tillmann 2009 (Erlandsson and Tillman 2009) Koplin et al. 2007 (Koplin et al. 2007) Mont and Plepys 2008 (Mont and Plepys 2008) Buysse and Verbeke 2003 (Buysse and Verbeke 2003) Kong et al. 2002 (Kong et al. 2002)
	Requirements for eco-labels – ISO 14020 (Type I (ISO 14024), Type II (ISO 14021) or Type III (ISO 14025), or environmental certificates managed by NGOs (ISO 14001, 14040, 14062), etc.	Standards	Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Business Strategy and the Environment European Management Journal	Li 2005 (Li and Geiser 2005) O'Rourke 2005 (O'Rourke 2005) de Boer 2003 (de Boer 2003) Albino 2009 (Albino et al. 2009) Kong et al. 2002 (Kong et al. 2002)
	NGOs campaigns targeted at raising sustainable awareness and changing consumer behavior, policies, and institutional buyers (positive information). Environmental pressure influencing "license to operate"	TV, newspapers, magazines, and internet observations and monitoring	Journal of Industrial Ecology Business Strategy and the Environment Journal of Cleaner Production European Management Journal	O'Rourke 2005 (O'Rourke 2005) de Boer 2003 (de Boer 2003) Moffat and Auer 2006 (Moffat and Auer 2006) Kong et al. 2002 (Kong et al. 2002)
	Partnerships and coalitions with firms regarding sustainable problem solving, product development, to ensure transparency, or promote community participation	TV, newspapers, magazines, and internet observations and monitoring	Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management European Management Journal	La France and Lehmann 2005 (LaFrance and Lehmann 2005) Stafford et al. 2000 (Stafford et al. 2000) Huijstee and Glasbergen 2008 (van Huijstee and Glasbergen 2008) Kong et al. 2002 (Kong et al. 2002)
	NGOs buying shares in firms to vote, launch campaigns, or lobby other shareholders	Stock news	Business Strategy and the Environment Business Strategy and the Environment	O'Rourke 2003 (O'Rourke 2005) Waygood and Whrmeyer 2003 (Waygood and Wehrmeyer 2003)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Media	Documentaries and campaigns targeted at specific products, substances, firms, or industries	TV, newspapers, magazines, and internet observations and monitoring (Facebook groups, discussion forums, product pages, blogs)	Journal of Cleaner Production	Erlandsson and Tillmann 2009 (Erlandsson and Tillman 2009)
	Interests, values, preferences, and dislikes on a product or firm	TV, newspapers, magazines, and internet observations and monitoring (Facebook groups, discussion forums, product pages, blogs)	Corporate Social Responsibility and Environmental Management European Management Journal	Cramer 2002 (Cramer 2002) Kong et al. 2002 (Kong et al. 2002)
	Social and environmental disclosure on internet on products, substances, firms, or industries	TV, newspapers, magazines, and internet observations and monitoring (Facebook groups, discussion forums, product pages, blogs)	Corporate Social Responsibility and Environmental Management	Tagesson 2009 (Tagesson et al. 2009)
Shareholders Investors	Expressions on sustainability issues expressed at shareholder meetings through	Stakeholder meetings: voting or discussions	Business Strategy and the Environment Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology European Management Journal	O'Rourke 2003 (O'Rourke 2005) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Koellner et al. 2007 (Koellner et al. 2007) Kong et al. 2002 (Kong et al. 2002)
	Decisions to invest, not to invest or divest in firms due to environmental, ethical or social concerns	Stakeholder collaboration and participation in networks	Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology	Alniacik et al. 2010 (Alniacik et al. 2010) Aslaksen and Synnestvedt 2003 (Aslaksen and Synnestvedt 2003) O'Rourke 2003 (O'Rourke 2005) Halme 2001 (Halme and Niskanen 2001) Koellner et al. 2007 (Koellner et al. 2007)
	Ethical, social and environmental investment criteria for funds	Stakeholder collaboration and participation in networks	Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology	Dobers and Wolff 2000 (Dobers and Wolff 2000) Schrader 2006 (Schrader 2006) Jayne and Skerrat 2003 (Jayne and Skerratt 2003) Koellner et al. 2007 (Koellner et al. 2007)

Scientific Community/ Academia	Priority settings for further research	Stakeholder Management, Participation in Networks	Business Strategy and the Environment	Bos-Brouwers 2009 (Bos-Brouwers 2009)
	Work and cooperation with standardization organizations	Stakeholder Management, Participation in Networks	Journal of Cleaner Production	Erlandsson and Tillmann 2009 (Erlandsson and Tillman 2009)
	Sustainability issues through knowledge exchange, practice transfer (workshops, students), and research	Stakeholder Management, Participation in Networks	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Erlandsson and Tillmann 2009 (Erlandsson and Tillman 2009) Duarte et al. 2008 (Duarte et al. 2008) Rotheroe et al. 2003 (Rotheroe et al. 2003) Foster and Green 2000 (Foster and Green 2000)
	Willingness to share the costs of innovation processes through partnerships with firms	Stakeholder Management, Participation in Networks	Journal of Cleaner Production	Duarte et al. 2008 (Duarte et al. 2008)
Industry Associations	Current or pending (up-coming) legislation	Stakeholder Management, Participation in Networks	Business Strategy and the Environment	Bos-Brouwers 2009 (Bos-Brouwers 2009)
	Sustainable technologies and sustainable issues	Stakeholder Management, Participation in Networks	Business Strategy and the Environment	Foster and Green 2000 (Foster and Green 2000)
	Transparency in decision making within the industry sector	Stakeholder Management, Participation in Networks	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
Financial Institutions	Environmental policy declarations, environmental stewardship, i.e. actions taken to decrease its own direct environmental impact (using certified ISO 14001 suppliers, recycling paper, reducing energy usage, attending to waste in a responsible manner…)	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements	Business Strategy and the Environment Corporate Social Responsibility and Environmental Management	Lundgren and Catasus 2000 (Lundgren and Catasus 2000) Weber et al. 2008 (Weber et al. 2008)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
	Sustainability "edged" financial products i.e. reduced interest rates for loans or insurance premium, or special funds for environmental improvements projects where the potential loss of a given loan is shared by sponsors	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements	Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Business Strategy and the Environment Business Strategy and the Environment	Weber et al. 2008 (Weber et al. 2008) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Minoli and Bell 2003 (Minoli and Bell 2003) Lundgren and Catasus 2000 (Lundgren and Catasus 2000)
	Checklists and criteria regarding environmental, ethical, and social risks by which banks, insurance firms, and investment institutions screen firms before investment (positive or negative criteria)	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Strategic Management Journal	Haigh and Guthrie 2010 (Haigh and Guthrie 2010) Schrader 2006 (Schrader 2006) Minoli and Bell 2003 (Minoli and Bell 2003) Lundgren and Catasus 2000 (Lundgren and Catasus 2000) Dobers and Wolff 2000 (Dobers and Wolff 2000) Weber et al. 2008 (Weber et al. 2008) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Aslaksen and Synnestvedt 2003 (Aslaksen and Synnestvedt 2003) Moffat and Auer 2006 (Moffat and Auer 2006) O'Rourke 2003 (O'Rourke 2005) Koellner et al. 2007 (Koellner et al. 2007) Buysse and Verbeke 2003 (Buysse and Verbeke 2003)
	Philanthropy activities including engagement in community and sponsoring of organizations or events	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements	Business Strategy and the Environment Journal of Cleaner Production	Lundgren and Catasus 2000 (Lundgren and Catasus 2000) O'Rourke 2003 (O'Rourke 2005)
	Commitment not the accept money laundering and illegal business	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements	Business Strategy and the Environment	Lundgren and Catasus 2000 (Lundgren and Catasus 2000)
	Commitment to increase transparency, i.e. to provide their stakeholders with detailed information regarding where the money comes from and for what purposes it is lent	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements	Business Strategy and the Environment Corporate Social Responsibility and Environmental Management	Lundgren and Catasus 2000 (Lundgren and Catasus 2000) Weber et al. 2008 (Weber et al. 2008)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Competitor	Competitor's product weight and volume.	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003)
	Competitor's expected lifetime and durability of product, reliability of the product, maintenance requirements and reparability, easy to upgrade, availability of supply parts for product.	Environmental Benchmarking	Journal of Cleaner Production Robotics and Computer-Integrated Manufacturing	Waage et al. 2005 (Waage et al. 2005) Ijomah et al. 2007 (Ijomah et al. 2007)
	Competitor's production technology.	Environmental Benchmarking	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Competitor's problematic materials used in product (use of toxic, persistent, bio-accumulative, fuel-based and ozone depleting chemicals or materials in manufacturing process, presence of banned chemicals in product or in packaging).	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003)
	Competitor's packaging materials, weight, volume, number of materials, and presence of recyclable materials.	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003)
	Competitor's transportation distance to customer/consumer.	Environmental Benchmarking	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Competitor's energy consumption during use of product, including usage scenarios.	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003)
	Competitor's waste, emissions, noise and vibrations generated during use of product.	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003)
	Competitor's use of fasteners, joints and connections, hybrid fixings in product, and use of standard parts.	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal Robotics and Computer-Integrated Manufacturing	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003) Ijomah et al. 2007 (Ijomah et al. 2007)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Competitor	Competitor's time for disassembly, modularity, easy identification of parts of the product.	Environmental Benchmarking	Journal of Cleaner Production Robotics and Computer-Integrated Manufacturing	Waage et al. 2005 (Waage et al. 2005) Ijomah et al. 2007 (Ijomah et al. 2007)
	Competitor's use of non-renewable, non-reusable, non-recyclable and non-sustainable materials in product (harvest or production)	Environmental Benchmarking	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Competitor's cost or purchase price for product	Environmental Benchmarking	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Competitor's communication and marketing material available to the public, including advertisements on web. sites, newspapers, magazines etc.)	Environmental Benchmarking	Journal of Cleaner Production Journal of Cleaner Production Benchmarking - An International Journal Journal of Cleaner Production	Moore and Manring 2009 (Moore and Manring 2009) Krucken and Meroni 2006 (Krucken and Meroni 2006) Boks and Stevels 2003 (Casper Boks 2003) Erlandsson and Tillmann 2009 (Erlandsson and Tillman 2009)
	Competitor's Cooperate Environmental policy, objectives, targets, and environmental management system (EMS).	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal Business Strategy and the Environment	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003) Springett 2003 (Springett 2003)
	Competitor's regular sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customer or market (LCA-results, TBL accounting, Dow Jones Sustainability Index, GRI, carbon footprint, ecological footprint, and water footprint)	Environmental Benchmarking	Journal of Industrial Ecology Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Wiedmann et al. 2009 (Wiedmann et al. 2009) Moore and Manring 2009 (Moore and Manring 2009) Nissinen et al. 2007 (Nissinen et al. 2007) Springett 2003 (Springett 2003)
	Competitor's environmental focused supplier program, including audits	Environmental Benchmarking	Journal of Cleaner Production Benchmarking - An International Journal	Waage et al. 2005 (Waage et al. 2005) Boks and Stevels 2003 (Casper Boks 2003)
	Competitor's employee environmental awareness, education and training program	Environmental Benchmarking	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
	Competitor's local labor practices (child labor, forced labor, discrimination (race, sex, religion), wage issues (fair play, overtime payment), unions (the right to collective bargaining), working hours, workplace health and safety issues (including exposure to toxic, persistent and bio-accumalitive substances), employee privacy, access to food, water and healthcare.	Strategic Benchmarking, Media Screening	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Competitor's adherence to ISO 14001 or EMAS.	Environmental Benchmarking	Journal of Cleaner Production Business Strategy and the Environment	Waage et al. 2005 (Waage et al. 2005) Steger et al. 2002 (Steger et al. 2002)
Consumers and Customers	Customer's environmental perception of the product (i.e.is the product considered better/worse than similar products on the market)	Environmental Benchmarking	Benchmarking - An International Journal Robotics and Computer-Integrated Manufacturing	Boks and Stevels 2003(Boks and Stevels 2003) Ijomah et al. 2007 (Ijomah et al. 2007)
	Sustainable performance requirements towards delivered product or service (customer environmental pressure on company, health and safety during use of product)	Stakeholder Management Program	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology	Walker et al. 2008 (Walker et al. 2008) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Waage et al. 2005 (Waage et al. 2005) Foster and Green 2000 (Foster and Green 2000) Berchicci and Bodewes 2005 (Berchicci and Bodewes 2005) Finster et al. 2001 (Finster et al. 2001)
	Usage scenarios on energy	Environmental Benchmarking	Journal of Cleaner Production Robotics and Computer-Integrated Manufacturing	Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Ijomah et al. 2007 (Ijomah et al. 2007)
	Consumer fashion and trends within the product segment, trend sensitivity, new desires, the wish to have up-to-date products	Consumer Research	Business Strategy and the Environment Benchmarking - An International Journal Robotics and Computer-Integrated Manufacturing	van Nes and Cramer 2005 (van Nes and Cramer 2006) Boks and Stevels (Boks and Stevels 2003) Ijomah et al. 2007 (Ijomah et al. 2007)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Consumers and Customers	Customer preferences for green products from green firms (long life time, easy to maintain and repair, low repair costs …, concern, knowledge on benefits of green alternatives and action in connection to price, quality and functionality (resulting in increased sales or boycotting a company's product)) Consumer acceptance for long lasting products, repair, or upgrading possibilities	Consumer Research, Stakeholder Management Program	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Futures	Moffat and Auer 2006 (Moffat and Auer 2006) Leire and Thidell 2005 (Leire and Thidell 2005) Michelini and Razzoli 2004 (Michelini and Razzoli 2004) Hirschl et al. 2003 (Hirschl et al. 2003) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002) Leire and Thidell 2005 (Leire and Thidell 2005) van Nes and Cramer 2005 (van Nes and Cramer 2006) McDonald and Oates 2006 (McDonald and Oates 2006b) Haddock-Fraser and Tourelle 2010 (Haddock-Fraser and Tourelle 2010) Prakash 2002 (Prakash 2002) Peattie 2001 (Peattie 2001) Tukker et al. 2010 (Tukker et al. 2010) Cooper 2005 (Cooper 2005) Finster et al. 2001(Finster et al. 2001) Gilg et al. 2005 (Gilg et al. 2005)
	Consumer preferences for eco-labeled products (Energy Star, Nordic Swan, EU Flower)	Consumer Research	Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Boyd et al. 2008 (Boyd et al. 2008) Leire and Thidell 2005 (Leire and Thidell 2005) Pedersen and Neergard 2006 (Pedersen and Neergaard 2006)
	Preferences for product oriented-, use oriented-, and result oriented services instead of physical products (immaterial consumption). Social barriers towards shared use of product or open minded towards renting and shared use	Consumer Research	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Journal of Industrial Ecology Business Strategy and the Environment Ecological Economics	Mont and Plepys 2008 (Mont and Plepys 2008) Altham 2007 (Altham 2007) Michelini and Razzoli 2004 (Michelini and Razzoli 2004) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Bartolomeo et al. 2003 (Bartolomeo et al. 2003) Manzini and Vezzoli 2003 (Manzini and Vezzoli 2003) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002) Hirschl et al. 2003 (Hirschl et al. 2003) Mont 2002 (Mont 2002) Tukker et al. 2010 (Tukker et al. 2010) Ny et al. 2008 (Ny et al. 2008) Peattie 2001 (Peattie 2001) Sanne 2002 (Sanne 2002)
	Consumer behavior in a social-cultural market context, values, beliefs, attitudes and actions. Decision to delay or avoiding making a purchase (what influence the purchase decision – attitudes, intentions and behavior).	Consumer Research	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment	Lane and Potter 2007 (Lane and Potter 2007) Leire and Thidell 2005 (Leire and Thidell 2005) Hirschl et al. 2003 (Hirschl et al. 2003) Boons 2002 (Boons 2002) Mont and Plepys 2008 (Mont and Plepys 2008) Pedersen and Neergard 2006 (Pedersen and Neergaard 2006) McDonald and Oates 2006 (McDonald and Oates 2006a) Chamorro et al. 2009 (Chamorro et al. 2009)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Consumers and Customers			Journal of Industrial Ecology Futures	Kaenzig and Wustenhagen 2009 (Kaenzig and Wüstenhagen 2010) Gilg et al. 2005 (Gilg et al. 2005)
	Consumer use of current products on market or similar products if product doesn't exist (focus on interface between human health, product/object, monitoring of direct impacts from the product (positive/negative) with respect to sustainability aspects during use)	Consumer Research	Business Strategy and the Environment Business Strategy and the Environment	Hoffmann 2007 (Hoffmann 2007) Peattie 2001 (Peattie 2001)
	The product's contribution to internal population shifts, i.e. from rural to urban areas.	Consumer Research, Social research	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Perceived personal factors and benefits from the product (satisfaction)	Consumer Research	Journal of Cleaner Production	Marchand and Walker 2008 (Marchand and Walker 2008)
	Sustainability awareness expressed as abstention (e.g. consuming less, better living with less- dematerialization), attitude (e.g. not exceeding basic needs), awareness (e.g. choosing ecological products) and alternatives (e.g. switching from product to service)	Consumer Research	Journal of Industrial Ecology Journal of Industrial Ecology Journal of Cleaner Production	Tukker et al. 2010 (Tukker et al. 2010) Jackson 2005 (Jackson 2005) Marchand and Walker 2008 (Marchand and Walker 2008)
	Ability to be engaged in the activity of "doing" with the product, the preference of intelligent products in the terms of constitution and functioning	Consumer Research	Journal of Cleaner Production Journal of Cleaner Production	Marchand and Walker 2008 (Marchand and Walker 2008) Mont and Plepys 2008 (Mont and Plepys 2008)
	Lock-ins and habits to unsustainable practices	Consumer Research	Journal of Industrial Ecology Ecological Economics	Tukker et al. 2010 (Tukker et al. 2010) Sanne 2002 (Sanne 2002)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Consumers and Customers	View on non-price based costs in the green purchase (gathering information about the product, effort to make the purchase, using or disposing the product a certain way)	Consumer Research	Business Strategy and the Environment Business Strategy and the Environment	Peattie 2001 (Peattie 2001) Meyer 2001 (Meyer 2001)
	Perception of company image (reputation) communicated through corporate social performance (CSP), responsibility (CSR) and responsiveness (CSR2), EMS and voluntary adherence to standards (EMAS, ISO 14001)	Stakeholder Management Programs	Corporate Social Responsibility and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology	Alniacik et al. 2010 (Alniacik et al. 2010) Haddock-Fraser and Tourelle 2008 (Haddock-Fraser and Tourelle 2010) Prakash 2002 (Prakash 2002) Del Río et al. 2010 (Del Río et al. 2010)
Suppliers	Local impacts on natural resources, land and biodiversity at suppliers' production facilities (non-renewable and non-sustainable materials, loss of land, loss of biodiversity)	Sustainable Supply Chain Management	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Journal of Industrial Ecology Journal of Cleaner Production Corporate Environmental Strategy Business Strategy and the Environment International Journal of Production Economics	Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Maxwell et al. 2006 (Maxwell et al. 2006) Waage et al. 2005 (Waage et al. 2005) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Rosen et al. 2002 (Rosen et al. 2002) Faruk et al. 2001 (Faruk et al. 2001) Koplin et al. 2007 (Koplin et al. 2007) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001) Darnall et al 2008 (Darnall et al. 2008) Piplani et al. 2008 (Piplani et al. 2008)
	Use and volume of hazardous substances in the product (toxic, persistent, bio-accumulative, fuel-based and ozone depleting chemicals or materials) in manufacturing process, in product or in packaging	Sustainable Supply Chain Management	Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Corporate Environmental Strategy	Rock et al. 2006 (Rock et al. 2006) Rosen et al. 2002 (Rosen et al. 2002) Faruk et al. 2001 (Faruk et al. 2001) Bos-Brouwers 2009 (Bos-Brouwers 2009) Handfield et al. 2005 (Handfield et al. 2005) Preuss 2005 (Preuss 2005) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001)
	Energy use (non-efficient, non-renewable and non- sustainable sources of energy), or commitment to energy saving projects	Sustainable Supply Chain Management	Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Business Strategy and the Environment Corporate Environmental Strategy	Rock et al. 2006 (Rock et al. 2006) Rosen et al. 2002 (Rosen et al. 2002) Faruk et al. 2001 (Faruk et al. 2001) Bos-Brouwers 2009 (Bos-Brouwers 2009) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Suppliers	Contribution to internal population shifts (i.e. from rural to urban areas).	Sustainable Supply Chain Management	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Regular sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customer or market (LCA, TBL accounting, GRI-reporting, carbon footprint, ecological footprint and water footprint)	Sustainable Supply Chain Management	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Bai and Sarkis 2010 (Bai and Sarkis 2010) Wiedmann et al. 2009 (Wiedmann et al. 2009) Seuring and Muller 2008 (Seuring and Müller 2008) Zhu et al. 2007 (Zhu et al. 2007) Bos-Brouwers 2009 (Bos-Brouwers 2009)
	Adherence to UN's Human Rights.	Sustainable Supply Chain Management	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Adherence to international, national, local legislation and voluntary initiatives in sustainability matters (i.e. EMAS, ISO 1400-series, Eco-labeling schemes, Dow Jones Sustainability Index)	Sustainable Supply Chain Management	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Journal of Industrial Ecology Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment	Bai and Sarkis 2010 (Bai and Sarkis 2010) Seuring and Muller 2008 (Seuring and Müller 2008) Kovacs 2008 (Kovács 2008) Maxwell et al. 2006 (Maxwell et al. 2006) Moore and Manring 2009 (Moore and Manring 2009) Rock et al. 2006 (Rock et al. 2006) Rosen et al. 2002 (Rosen et al. 2002) Faruk et al. 2001 (Faruk et al. 2001) Clift et al. (Clift et al. 2005) Darnall et al. 2008 (Darnall et al. 2008) Handfield et al. 2005 (Handfield et al. 2005) Preuss 2005 (Preuss 2005)
	Philanthropy activities including engagement in community and sponsoring of organizations or events	Sustainable Supply Chain Management	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Corporate Environmental Strategy	Hutchins and Sutherland 2008 (Hutchins and Sutherland 2008) Maxwell et al. 2006 (Maxwell et al. 2006) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Bos-Brouwers 2009 (Bos-Brouwers 2009) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001)
	Direct and indirect employment in developing countries, the ethics in business decisions regarding 2nd and 3rd world countries (e.g. product development activities specifically for developing countries)	Sustainable Supply Chain Management	Business Strategy and the Environment Corporate Environmental Strategy	Bos-Brouwers 2009 (Bos-Brouwers 2009) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Suppliers	Education training programs for employees (environmental and other)	Sustainable Supply Chain Management	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Cleaner Production Corporate Environmental Strategy	Bos-Brouwers 2009 (Bos-Brouwers 2009) Darnall et al. 2008 (Darnall et al. 2008) Handfield et al. 2005 (Handfield et al. 2005) Bai and Sarkis 2010 (Bai and Sarkis 2010) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001)
	Supplier's labor practices (child labor, forced labor, discrimination (race, sex, religion), wage issues (fair play, overtime payment), unions (the right to collective bargaining), working hours, workplace health and safety issues (including exposure to toxic, persistent and bio-accumulative substances), employee privacy, access to food, water and healthcare)	Sustainable Supply Chain Management	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Corporate Environmental Strategy	Hutchins and Sutherland 2008 (Hutchins and Sutherland 2008) Maxwell et al. 2006 (Maxwell et al. 2006) Waage et al. 2005 (Waage et al. 2005) Maxwell et al. 2003 (Maxwell and van der Vorst 2003) Bos-Brouwers 2009 (Bos-Brouwers 2009) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001)
	Supplier's commitment to advertising norms, i.e. responsible marketing (not provide damaging offerings and not directed to vulnerable groups (marketing to children, misrepresentation, etc.)	Sustainable Supply Chain Management	Journal of Cleaner Production Corporate Environmental Strategy	Tukker et al. 2008 (Tukker et al. 2008) Young and Kielkiewicz-Young 2001(Young and Kielkiewicz-Young 2001)
	Support to oppressive regimes.	Sustainable Supply Chain Management	Corporate Environmental Strategy	Young and Kielkiewicz-Young 2001 (Young and Kielkiewicz-Young 2001)
	Honesty, trust, respect and fairness in corporate or organizational relations (e.g. not to use bribery and corruption)	Sustainable Supply Chain Management	Corporate Environmental Strategy	Young and Kielkiewicz-Young 2001 (Young and Kielkiewicz-Young 2001)
	Use of reusable and recyclable materials. Supplier's contribution to incineration or landfills through production	Sustainable Supply Chain Management	Journal of Industrial Ecology Journal of Industrial Ecology Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology	Rosen et al. 2002 (Rosen et al. 2002) Faruk et al. 2001 (Faruk et al. 2001) Handfield et al. 2005 (Handfield et al. 2005) Bos-Brouwers 2009 (Bos-Brouwers 2009) Rock et al. 2006 (Rock et al. 2006)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Suppliers	Frameworks for maintenance, packaging and distribution of products (reduce, reuse, and recycling of product packing materials and methods).	Sustainable Supply Chain Management	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology Journal of Industrial Ecology Journal of Cleaner Production	Thun and Muller 2010 (Thun and Muller 2010) Bos-Brouwers 2009 (Bos-Brouwers 2009) Handfield et al. 2005 (Handfield et al. 2005) Preuss 2005 (Preuss 2005) Rock et al. 2006 (Rock et al. 2006) Rosen et al. 2002 (Rosen et al. 2002) Zhu et al. 2007 (Zhu et al. 2007)
	Service, price, quality, cost and delivery.	Sustainable Supply Chain Management	Business Strategy and the Environment	Preuss 2005 (Preuss 2005)
	Location (distance) and transportation means of products (water, rail, road, air)	Sustainable Supply Chain Management	Business Strategy and the Environment Business Strategy and the Environment Journal of Cleaner Production Journal of Industrial Ecology	Bos-Brouwers 2009 (Bos-Brouwers 2009) Preuss 2005 (Preuss 2005) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Faruk et al. 2001 (Faruk et al. 2001)
	Innovation and product development abilities, and knowledge on new technologies	Sustainable Supply Chain Management	Business Strategy and the Environment Business Strategy and the Environment Journal of Cleaner Production	Darnall et al. 2008 (Darnall et al. 2008) Foster and Green 2000 (Foster and Green 2000) Bai and Sarkis 2010 (Bai and Sarkis 2010)
	Supplier's financial situation and stability	Sustainable Supply Chain Management	Business Strategy and the Environment	Preuss 2005 (Preuss 2005)
	Corporate environmental responsibility (CER) and environmental management system (EMS) (i.e stance towards the environment)	Sustainable supply chain management	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology Journal of Industrial Ecology Journal of Cleaner Production Journal of Cleaner Production Corporate Environmental Strategy	Darnall et al. 2008 (Darnall et al. 2008) Handfield et al 2005 (Handfield et al. 2005) Preuss 2005 (Preuss 2005) Rock et al. 2006 (Rock et al. 2006) Rosen et al. 2002 (Rosen et al. 2002) Kovacs 2008 (Kovács 2008) Nawrocka and Parker 2009 (Nawrocka and Parker 2009) Young and Kielkiewicz-Young (Young and Kielkiewicz-Young 2001)
	Supplier's internal employee satisfaction and participation in decision making	Sustainable Supply Chain Management	Business Strategy and the Environment Journal of Purchasing and Supply Management	Bos-Brouwers 2009 (Bos-Brouwers 2009) Walker 2008 (Walker et al. 2008)
	Supplier's supplier selection programs and purchasing policy including training on life cycle impacts of the product/service and environmental and social objectives	Sustainable Supply Chain Management	Business Strategy and the Environment Business Strategy and the Environment Corporate Environmental Strategy	Thun and Muller 2010 (Thun and Muller 2010) Handfield et al. 2005 (Handfield et al. 2005) Young and Kielkiewicz-Young (Young and Kielkiewicz-Young 2001)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Suppliers	Supplier's sustainability orientation (eco-efficiency, cost-effective) and compliance orientation (no more than minimum).	Sustainable Supply Chain Management	Business Strategy and the Environment	Bos-Brouwers 2009 (Bos-Brouwers 2009)
Internal Stakeholders (management, employees)	Stakeholder performance requirements and information (environmental and sustainable) received at different functions and levels in the firms	Stakeholder dialog collaboration, and partnerships	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology	Bos-Brouwers 2009 (Bos-Brouwers 2009) Plaza-Ubeda et al. 2009 (Plaza-Ubeda et al. 2009) Gonzalez-Bentito and Gonzalez-Bentito 2008 (González-Benito and González-Benito 2008) Madsen and Ulhøi 2001(Madsen and Ulhøi 2001) Foster and Green 2000 (Foster and Green 2000) Delmas 2004 (Delmas and Toffel 2004) Cramer 2002 (Cramer 2002) Del Rio 2010 (Del Río et al. 2010)
	Commitment and adherence to corporate social responsibility (CSR), environment responsibility (CER), and environmental management systems (EMS)	Internal communication and information flows	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology	Paulraj 2009 (Paulraj 2009) Lankoski 2007 (Lankoski 2008) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Roy et al. 2001 (Roy et al. 2001) Yakhou and Dorweiler 2004 (Yakhou and Dorweiler 2004) Springett 2003 (Springett 2003) Nawrocka and Parker 2009 (Nawrocka and Parker 2009) Welford et al. 2008 (Welford et al. 2008) O'Conner and Spangenberg 2008 (O'Connor and Spangenberg 2008) Waage 2007 (Waage 2007) Tukker et al. 2008 (Tukker et al. 2008) Zsoka 2008 (Nemcsicsné Zsóka 2008) Castka et al. 2004 (Castka et al. 2004) Callan and Thomas 2009 (Callan and Thomas 2009) Jayne and Skerrat 2003 (Jayne and Skerratt 2003) Alniacik et al. 2010 (Alniacik et al. 2010) Koellner et al. 2007 (Koellner et al. 2007)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)	Motivational activities towards customers to promote recovery of products and components for reuse, recycling or treatment/disposal, and to keep records and track where the company's products are (EOL instructions)	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology Business Strategy and the Environment	Tsoulfas and Pappis 2008 (Tsoulfas and Pappis 2008) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002) Ny et al. 2008 (Ny et al. 2008) Gonzalez-Bentito and Gonzalez-Bentito 2006 (González-Benito and González-Benito 2006)
	Investment and commitment in employee training, education, skills (general and in green competencies), motivation and involvement in decision making	Internal communication and information flows	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology Strategic Management Journal	Paulraj 2009 (Paulraj 2009) Bos-Brouwers 2009 (Bos-Brouwers 2009) Plaza-Ubeda et al. 2009 (Plaza-Ubeda et al. 2009) Darnall et al. 2008 (Darnall et al. 2008) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Roy et al. 2001 (Roy et al. 2001) Handfield et al. 2005 (Handfield et al. 2005) Zsoka 2008 (Nemcsicsné Zsóka 2008) Walker et al. 2008 (Walker et al. 2008) Tsoulfas and Pappis 2008 (Tsoulfas and Pappis 2008) Waage et al. 2005 (Waage et al. 2005) Seuring and Muller 2008 (Seuring and Müller 2008) Gallego 2006 (Gallego 2006) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Koellner et al. 2007 (Koellner et al. 2007) Buysse and Verbekke 2003 (Buysse and Verbeke 2003)
	Commitment to use effective environmental accounting systems and management tools with performance indicators (i.e.TBL accounting, EPD, GRI)	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of cleaner Production Journal of cleaner Production Journal of cleaner Production Journal of cleaner Production Journal of cleaner Production Journal of cleaner Production Journal of cleaner Production Journal of cleaner Production Journal of Cleaner Production Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management	Zsoka 2008 (Nemcsicsné Zsóka 2008) O'Conner and Spangenberg 2008 (O'Connor and Spangenberg 2008) Steen et al. 2008 (Steen et al. 2008) Tsoulfas and Pappis 2008 (Tsoulfas and Pappis 2008) Nordheim and Barrasso 2007 (Nordheim and Barrasso 2007) Jasch and Lavicka 2006 (Jasch and Lavicka 2006) Jasch 2006 (Jasch 2006) Michelini and Razzoli 2004 (Michelini and Razzoli 2004) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Jasch 2003 (Jasch 2003) Olsthoorn et al. 2001(Olsthoorn et al. 2001) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Yakhou and Dorweiler 2004 (Yakhou and Dorweiler 2004) Jayne and Skerratt 2003 (Jayne and Skerratt 2003)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)			Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology	Koellner et al. 2007 (Koellner et al. 2007) Morhardt et al. 2002 (Morhardt et al. 2002)
	Commitment to include service policies that are provided to the customer during the use phase of products (to improve eco-efficiency and prolonged life of product) and to provide update policies for products that are provided to customers	Internal communication and information flows	Journal of Cleaner Production	Tsoulfas and Pappis 2008 (Tsoulfas and Pappis 2008)
	Commitment to involve users and other stakeholders in product development to enhance organizational and individual learning	Stakeholder dialog collaboration, and partnerships	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology European Management Journal	Walker et al. 2008 (Walker et al. 2008) Waage et al. 2005 (Waage et al. 2005) Kjaerheim 2005 (Kjaerheim 2005) Waage 2005 (Waage et al. 2005) Hoffmann 2007 (Hoffmann 2007) Madsen and Ulhøi 2001 (Madsen and Ulhøi 2001) Ny et al. 2008 (Ny et al. 2008) Kong et al. 2002 (Kong et al. 2002)
	Company labor practices (child labor, forced labor, discrimination (race, sex, religion), wage issues (fair play, overtime payment), unions (the right to collective bargaining), working hours, workplace health and safety issues (including exposure to toxic, persistent and bio-accumulative substances), employee privacy, access to food, water and healthcare	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Business Strategy and the Environment Business Strategy and the Environment Journal of Industrial Ecology	O'Conner and Spangenberg 2008 (O'Connor and Spangenberg 2008) Moffat and Auer 2006 (Moffat and Auer 2006) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Waage et al. 2005 (Waage et al. 2005) Welford et al. 2008 (Welford et al. 2008) Gallego 2006 (Gallego 2006) Castka et al 2004 (Castka et al. 2004) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Bos-Brouwers 2009 (Bos-Brouwers 2009) Plaza-Ubeda et al. 2009 (Plaza-beda et al. 2009) Figge and Hahn 2005 (Figge and Hahn 2005)
	Investments in clean/environmental technologies	Internal communication and information flows	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment	Plaza-Ubeda et al. 2009 (Plaza-beda et al. 2009) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Lindell and Karagozoglu 2001 (Lindell and Karagozoglu 2001)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)	Commitment to use reusable or recyclable packaging/containers for transportation of goods	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Michelini and Razzoli 2004 (Michelini and Razzoli 2004) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006)
	Freedom of speech and open information in firm	Internal communication and information flows	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)
	Firs regular sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customer or market (LCA, EPD, TBL accounting, GRI, CSR, carbon footprint, ecological footprint, water footprint, environmental reports)	Stakeholder dialog collaboration, and partnerships	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology	Wiedmann et al. 2009 (Wiedmann et al. 2009) Zackrisson et al. 2008 (Zackrisson et al. 2008) Moffat and Auer 2006 (Moffat and Auer 2006) Waage et al. 2005 (Waage et al. 2005) Daub 2005 (Daub 2007) Kjaerheim 2005 (Kjaerheim 2005) Jasch 2006 (Jasch 2006) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Morhardt 2010 (Morhardt 2010) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Blomquist 2004 (Blomquist and Sandström 2004) Marshall and Brown 2003 (Scott Marshall and Brown 2003) Welford et al. 2008 (Welford et al. 2008) Gallego 2006 (Gallego 2006) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Nijhof et al. 2002 (Nijhof et al. 2002) Wells and Orsato 2005 (Wells and Orsato 2005)
	Excessive use of materials, non-renewable, or hazardous materials in manufacturing or support processes (non-ecoefficiency)	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Kjaerheim 2005 (Kjaerheim 2005) Waage et al. 2005 (Waage et al. 2005) Michelini and Razzoli 2004 (Michelini and Razzoli 2004) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002) Gonzalez-Bentito and Gonzalez-Bentito 2006 (González-Benito and González-Benito 2006)
	Excessive generation of waste from manufacturing processes, including scrap products	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production	Kjaerheim 2005 (Kjaerheim 2005) Michelini and Razzoli 2004 (Michelini and Razzoli 2004) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)	EOL handling of product (reduce, reuse, recycle…..)		Journal of Cleaner Production Business Strategy and the Environment Journal of Industrial Ecology Journal of Industrial Ecology Corporate Social Responsibility and Environmental Management	Waage et al. 2005 (Waage et al. 2005) Gonzalez-Bentito and Gonzalez-Bentito 2006 (González-Benito and González-Benito 2006) Ny et al. 2008 (Ny et al. 2008) Wells and Orsato 2005 (Wells and Orsato 2005) Jayne and Skerratt 2003 (Jayne and Skerratt 2003)
	Excessive use of energy during manufacturing, support processes or use phase, use of non-efficient, non-renewable and non-sustainable of energy sources	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Corporate Social Responsibility and Environmental Management	Waage et al. 2005 (Waage et al. 2005) Kjaerheim 2005 (Kjaerheim 2005) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002) Gonzalez-Bentito and Gonzalez-Bentito 2006 (González-Benito and González-Benito 2006) Jayne and Skerratt 2003 (Jayne and Skerratt 2003)
	Company impacts on local natural resources, land and biodiversity at production facilities (incl. release of air pollutants, hazardous chemicals)	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management Journal of Industrial Ecology Journal of Industrial Ecology	Waage et al. 2005 (Waage et al. 2005) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Kjaerheim 2005 (Kjaerheim 2005) Waage et al. 2005 (Waage et al. 2005) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Figge and Hahn 2005 (Figge and Hahn 2005) Ny et al. 2008 (Ny et al. 2008)
	Firm's impact and involvement in local and global community through production, consumption and production EOL	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management	Waage et al. 2005 (Waage et al. 2005) Maxwell and van der Vorst 2003 (Maxwell and van der Vorst 2003) Gallego 2006 (Gallego 2006)
	Commitment to transparency in firm decision making	Internal communication and information flows	Journal of Cleaner Production Business Strategy and the Environment	Waage et al. 2005 (Waage et al. 2005) Bos-Bouwers 2009 (Bos-Brouwers 2009)
	Commitment to avoid bribery and corruption, and transparency regarding political contributions	Internal communication and information flows	Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Journal of Cleaner Production	Welford et al. 2008 (Welford et al. 2008) Gallego 2006 (Gallego 2006) Waage et al. 2005 (Waage et al. 2005)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)	Philanthropy activities including engagement in community and sponsoring of organizations or events	Internal communication and information flows	Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Journal of Cleaner Production Business Strategy and the Environment	Nijhof et al 2002 (Nijhof et al. 2002) Welford et al. 2008 (Welford et al. 2008) O'Conner and Spangenberg 2008 (O'Connor and Spangenberg 2008) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006)
	Stakeholders partnerships, and dialogs and involvement in decision making	Internal communication and information flows	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Journal of Cleaner Production Journal of Cleaner Production Journal of Industrial Ecology	Thun and Muller 2010 (Thun and Muller 2010) Sharfman et al. 2009 (Sharfman et al. 2009) Bos-Browers 2009 (Bos-Brouwers 2009) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Delmas and Toffel 2004 (Delmas and Toffel 2004) Oxley Green and Hunton-Clarke 2003 (Oxley Green and Hunton-Clarke 2003) Springett 2008 (Springett 2003) Catska et al. 2004 (Castka et al. 2004) Nijhof et al. 2002 (Nijhof et al. 2002) Welford et al. 2008 (Welford et al. 2008) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Kjaerheim 2005 (Kjaerheim 2005) Ny et al. 2008 (Ny et al. 2008)
	Company discharge permits and permits applications.	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management	Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Waage et al. 2005 (Waage et al. 2005) Jayne and Skerratt 2003 (Jayne and Skerratt 2003)
	LCA-results for product or process, ecological footprint, or Carbon footprint.	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment	Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Nissinen et al. 2007 (Nissinen et al. 2007) Tingstrøm et al. 2006 (Tingström et al. 2006) Kjaerheim 2005 (Kjaerheim 2005) Ekvall et al. 2005 (Ekvall et al. 2005) Waage et al. 2005 (Waage et al. 2005) Gehin et al. 2008 (Gehin et al. 2008) Schmidt & Schwegler 2008 (Schmidt and Schwegler 2008) Seuring 2004 (Seuring 2004a)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)			Business Strategy and the Environment	Foster and Green 2000 (Foster and Green 2000)
	Adherence to the requirements for eco-labeling (e.g. EU-flower, EU Energy Label, Nordic Swan, German Blue angels, Eco Mark, Forest Stewardship Council (FSC), Marine Stewardship Council (MSC), Fair Trade, Dolphin Safe, Green Electricity, Energy Star)	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Corporate Social Responsibility and Environmental Management Energy Policy European Management Journal Journal of Industrial ecology	Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Waage et al. 2005 (Waage et al. 2005) Michelini and Razzoli 2004 (Michelini and Razzoli 2004) Leire and Thidell 2005 (Leire and Thidell 2005) Tukker et al. 2008 (Tukker et al. 2008) De Boer 2003 (de 2003) Solér et al. 2010 (Solèr et al. 2010) Blomquist and Sandstrom 2004 (Blomquist and Sandström 2004) Handfield et al. 2005 (Handfield et al. 2005) Cramer 2002 (Cramer 2002) McWhinney et al.2005 (McWhinney et al. 2005) Kong et al. 2002 (Kong et al. 2002) Clift et al. 2005 (Clift et al. 2005)
	Adherence to the requirements for ISO 14000-series standardization and EMAS including KPI's	Internal communication and information flows	Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Business Strategy and the Environment Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management European Management Journal	Plaza-Ubeda et al. 2009 (Plaza-Ubeda et al. 2009) Nawrocka and Parker 2009 (Nawrocka and Parker 2009) Zsoka 2008 (Nemcsicsné Zsóka 2008) Darnall et al. 2008 (Darnall et al. 2008) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Blomquist and Sandstrom 2004 (Blomquist and Sandström 2004) Yakhou and Dorweiler 2004 (Yakhou and Dorweiler 2004) Marshall and Brown 2003 (Scott Marshall and Brown 2003) Foster and Green 2000 (Foster and Green 2000) Seuring and Muller (Seuring and Müller 2008) Steger 2002 (Steger et al. 2002) Handfield et al. 2005 (Handfield et al. 2005) Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Walker et al. 2008 (Walker et al. 2008) Tsoulfas and Pappis 2008 (Tsoulfas and Pappis 2008) Koplin et al. 2007 (Koplin et al. 2007) Zhu et al. 2007 (Zhu et al. 2007) Jasch 2000 (Jasch 2000) Jayne and Skerratt 2003 (Jayne and Skerratt 2003) Cramer 2002 (Cramer 2002) Kong et al. 2002(Kong et al. 2002)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)	Company adherence to social issues requirements (SA 8000), fair labor code of conduct, ILO's Decent Work and standard regarding ethical issues of businesses (AA1000) and GRI	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management	Koplin et al. 2007 (Koplin et al. 2007) Waage et al. 2005 (Waage et al. 2005) Seuring and Muller 2008 (Seuring and Müller 2008) Cramer 2002 (Cramer 2002) Jayne and Skerratt 2003 (Jayne and Skerratt 2003)
	Involvement and sharing of product environmental responsibility with suppliers	Internal communication and information flows	Business Strategy and the Environment	Thun and Muller 2010 (Thun and Muller 2010)
	Commitment to advertising norms, i.e. responsible marketing (i.e. green washing, not provide damaging offerings)	Internal communication and information flows	Journal of Cleaner Production Journal of Cleaner Production Journal of Cleaner Production Corporate Social Responsibility and Environmental Management Corporate Social Responsibility and Environmental Management Business Strategy and the Environment Ecological Economics	Waage et al. 2005 (Waage et al. 2005) Tukker et al. 2008 (Tukker et al. 2008) Erlandsson and Tillman 2009 (Erlandsson and Tillman 2009) Gallego 2006 (Gallego 2006) Welford et al. 2008 (Welford et al. 2008) Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Sanne 2002 (Sanne 2002)
	Commitment to fair pricing and competition	Internal communication and information flows	Journal of Cleaner Production Corporate Social Responsibility and Environmental Management	Waage et al. 2005 (Waage et al. 2005) Gallego 2006 (Gallego 2006)
	Commitment to use cleaner transportation methods	Internal communication and information flows	Business Strategy and the Environment Journal of Cleaner Production	Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006) Van Hemel and Cramer 2002 (van Hemel and Cramer 2002)
	CSR or green activities giving average positive profit margins (not above or below average)	Internal communication and information flows	Corporate Social Responsibility and Environmental Management Business Strategy and the Environment Journal of Industrial Ecology	Blomgren 2010 (Blomgren 2010) Halme and Niskanen 2001(Halme and Niskanen 2001) Lenox and King 2001 (Lenox and Nash 2003)
	Firm's contribution to internal population shifts from rural to urban areas	Internal communication and information flows	Journal of Cleaner Production	Waage et al. 2005 (Waage et al. 2005)

Stakeholder	Importance and Accuracy	Accessibility	Journal	Literature reference
Internal Stakeholders (management, employees)	Commitment to sustainable and green supply chain practices (SSCM and GSCM) assessing the sustainability performance of suppliers, and imposing higher standards	Internal communication and information flows	Business Strategy and the Environment	Thun and Muller 2010 (Thun and Muller 2010)
			Business Strategy and the Environment	Bos-Brouwers 2009 (Bos-Brouwers 2009)
			Business Strategy and the Environment	Paulraj 2009 (Paulraj 2009)
			Business Strategy and the Environment	Darnall et al. 2008 (Darnall et al. 2008)
			Business Strategy and the Environment	Gonzalez-Benito and Gonzalez-Benito 2006 (González-Benito and González-Benito 2006)
			Business Strategy and the Environment	Seuring 2004 (Seuring 2004a)
			Business Strategy and the Environment	O'Conner and Spangenberg 2008 (O'Connor and Spangenberg 2008)
			Business Strategy and the Environment	Handfield 2005 (Handfield et al. 2005)
			Business Strategy and the Environment	Soler 2010 (Solèr et al. 2010)
			Business Strategy and the Environment	Sharfman 2009 (Sharfman et al. 2009)
			Journal of Cleaner Production	Walker et al. 2008 (Walker et al. 2008)
			Journal of Cleaner Production	Tsoulfas and Pappis 2008 (Tsoulfas and Pappis 2008)
			Journal of Cleaner Production	Koplin et al. 2006 (Koplin et al. 2007)
			Journal of Cleaner Production	Kjaerheim 2005 (Kjaerheim 2005)
			Journal of Cleaner Production	Ny et al. 2008 (Ny et al. 2008)
			Journal of Cleaner Production	Gold et al. 2010 (Gold et al. 2010)
			Journal of Industrial Ecology	Welford et al. 2008 (Welford et al. 2008)
			Corporate Social Responsibility and Environmental Management	Schmidt 2008 (Schmidt and Schwegler 2008)
			Corporate Social Responsibility and Environmental Management	Jayne and Skerrat 2003 (Jayne and Skerratt 2003)
			International Journal of Management Reviews	Srivastava 2007 (Srivastava 2007)

12. Results – The sustainability information framework

Stakeholder group	Life cycle stage	Description of sustainability information element ("information on….")	Accessibility
Government	All	Registration, Evaluation and Authorization of Chemicals (REACh)	REACh EC Directive
	All	EcoDesign Directive for Energy Using Products (EuP)	EuP EC Directive
	All	Restriction of the Use of Certain Hazardous Substances in Electrical Equipment (RoHS)	RoHS EC Directive
	All	European Commission Green Paper on Integrated Product Policy (IPP)	IPP EC Green Paper
	All	Purchasing guidelines and requirements for social and environmental responsible public procurement	Governmental and institutional purchase guidelines. Invitation to submit tenders, etc.
	All	Export/import countries' sustainability regulations	National Governments
	All	Pre-regulations (new regulations) concerning sustainability issues	National Governments, EC
	All	Governmental campaigns targeted at raising sustainable awareness and changing consumer behavior	
	Manufacturing	National guidelines and priorities within Integrated Pollution Prevention and Control (IPPC)	National Governments
	Transport	Packaging and Packaging Waste	Packaging Waste EC Directive
	Disposal	End-of-Life Vehicle (ELV)	ELV EC Directive
	Disposal	The Waste from Electric and Electronic Equipment (WEEE)	WEEE EC Directive
	Disposal	National extended producer responsibilities (EPR) (including take-back or EOL handling obligations for producer)	National EPR requirements
NGOs	All	Campaigns targeted at specific products, substances, firms, practices, or industries (negative information)	TV, newspapers, magazines, and internet observations and monitoring
	All	Campaigns targeted at raising sustainable awareness and changing consumer behavior and firm procurements policies (positive information)	
	All	Partnerships and coalitions with firms regarding sustainable problem solving, product development, to ensure transparency, or promote community participation	
	All	Sustainable performance test results and ranking lists	
	All	Requirements for sustainability-labeling or sustainability certificates managed by NGOs	Standards
	All	Buying shares in firms to vote, launch campaigns, or lobby other shareholders	Stock news

Stakeholder group	Life cycle stage	Description of sustainability information element ("information on….")	Accessibility
Media	All	Documentaries and campaigns targeted at specific products, substances, firms, or industries (negative information)	TV, newspapers, magazines, and internet observations and monitoring (Facebook groups, discussion forums, product pages, blogs)
	All	Interests, values, preferences, and dislikes related to a product or firm	
	All	Social and environmental disclosures on internet on products, substances, firms, or industries	
Shareholders/Investors	All	Attitudes and values on sustainability issues	Shareholder meetings: voting or discussions
	All	Decisions to invest, not to invest, or divest in firms due to sustainability concerns	
	All	Sustainability investment criteria for funds	
Scientific Community/ Academia	All	Priority settings for new sustainability related research areas and calls	Stakeholder collaboration and participation in networks
	All	Work and cooperation with standardization organizations	
	All	Sustainability issues through knowledge exchange, practice transfer (workshops, students), and research	
	All	Willingness to share the costs of innovation processes through partnerships with firms	
Industry Assoc.	All	Current or pre-regulations concerning sustainability issues	Stakeholder collaboration and participation in networks
	All	Transparency in decision making within the industry sector	
	Manufacturing	Sustainable technologies and other relevant sustainable issues	
Financial Institutions	All	Sustainability policy declarations and sustainable stewardship	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements
	All	Sustainability "edged" financial products	
	All	Checklists and criteria regarding sustainability risks (positive or negative criteria)	
	All	Philanthropy activities including engagement in community and sponsoring of organizations or events	
	All	Commitment not to accept money laundering and illegal business	
	All	Commitment to increase transparency, i.e. to provide their stakeholders with detailed information regarding where the money comes from and for what purposes it is lent out	

Stakeholder group	Life cycle stage	Description of sustainability information element ("information on….")	Accessibility
Competitors	All	Communication and marketing materials on sustainability issues	Sustainability benchmarking
	All	Corporate sustainability policies and management systems	
	All	Sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customers or markets (e.g. AA1000, GRI)	
	All	Education and training programs for employees (environmental and other programs)	
	All	Labor practices (SA 8000, fair labor code of conduct, and ILO's Decent Work standard)	
	All	Adherence to legislation or voluntary sustainability-labeling or sustainability certificates/standards	
	Materials	Use and volume of hazardous substances, reusable or recyclable materials, or unsustainable materials in the product or in packaging	
	Materials	Sustainability focused supplier programs, including audits	
	Materials, Use	Fasteners, connections, modularity, standard parts, weight, and volume	
	Manufacturing	Use of sustainable production technology	
	Transport	Frameworks for reusable or recyclable packaging/containers for transportation of goods	
	Transport	Location (distance) and means of transportation of products (water, rail, road, air)	
	Use	Energy consumption during use of product, including usage scenarios	
	Use	Waste, emissions, noise, and vibrations generated during use of product	
	Use	Cost or purchase price for product	
	Use, Disposal	Lifetime, durability, reliability, upgrade options, maintenance requirements, and EOL scenarios	
Suppliers	All	Corporate sustainability policies and management systems	Sustainable supply chain management
	All	Supplier's general sustainability orientation and compliance orientation (more than minimum)	
	All	Sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customers or markets (e.g. AA1000, GRI)	
	All	Adherence to legislation or voluntary sustainability-labeling or sustainability certificates/standards	
	All	Contribution to internal population shifts (e.g. from rural to urban areas)	

Stakeholder group	Life cycle stage	Description of sustainability information element ("information on….")	Accessibility
	All	Philanthropy activities including engagement in community and sponsoring of organizations or events	
	All	Adherence to the UN Human Rights Declaration	
Suppliers	All	Direct and indirect employment in developing countries	Sustainable supply chain management
	All	Education and training programs for employees (sustainability related and other programs)	
	All	Labor practices (SA 8000, fair labor code of conduct, and ILO's Decent Work standard)	
	All	Commitment to advertising norms, i.e. responsible marketing	
	All	Support of oppressive regimes	
	All	Honesty, trust, respect, and fairness in business relations	
	All	Service, price, quality, cost, and delivery	
	All	Innovation abilities and product development activities	
	All	Financial situation and stability	
	All	Internal employee satisfaction and participation in decision making	
	Materials, Manufacturing	Local impacts on natural resources, land, and biodiversity at suppliers' production facilities	
	Materials	Use and volume of hazardous substances, reusable or recyclable materials, or unsustainable materials in the product or in packaging	
	Materials	Energy use (non-efficient, non-renewable and non-sustainable sources of energy), or commitment to energy saving projects	
	Materials	Volume and use of materials, use of reusable and recyclable materials	
	Materials	Supplier's supplier selection programs and purchasing policy	
	Transport	Frameworks for reusable or recyclable packaging/containers for transportation of goods	
	Transport	Location (distance) and means of transportation of products (water, rail, road, air)	
Customers (Value chain and end-customers)	All	Perception of the firm's sustainability image (reputation)	Stakeholder collaboration, customer research
	All	Preferences for sustainability-labeled products or sustainability certificates	
	All	Sustainability perception of the product (e.g. if the product is considered better/worse than similar products on the market)	
	All	Sustainable performance requirements towards delivered product or service	
	All	Preference for sustainable products from sustainable firms	
	All	Fashions and trends within the product segment, trend sensitivity, the wish to have up-to-date products	
	All	Behavior in a social-cultural market context, what influences the purchase decision	

Stakeholder group	Life cycle stage	Description of sustainability information element ("information on….")	Accessibility
	All	The product's contribution to internal population shifts (e.g. from rural to urban areas)	
	All	Sustainability awareness	
	All	View on non-price based costs (gathering information about the product, effort to make the purchase, using or disposing of the product a certain way)	
Customers	Use	Energy consumption during use of product, including usage scenarios	
	Use	Preferences for services instead of physical products. Social barriers towards shared use of products or open-mindedness towards renting and shared use	
	Use	Use of current products on market or similar products if product does not exist, with respect to sustainability aspects (lifetime, durability, reliability, upgrade options, maintenance requirements, and EOL scenarios)	
	Use	Perceived personal factors and benefits from the product (satisfaction), perceived product meaning	
	Use	Ability to be engaged in the activity of "doing" things with the product, the preference for intelligent products	
	Use	Lock-ins and habits of unsustainable practices	
Internal Stakeholders (management, employees)	All	Stakeholder sustainable performance requirements and information received at different functions and levels in the firms	Stakeholder collaboration and partnerships
	All	Commitment to involve users and other stakeholders in product development to enhance organizational and individual learning	
	All	Stakeholders' partnerships and dialogs and involvement in decision making, communication with stakeholder groups (e.g. AA1000, GRI)	
	All	Commitment and adherence to corporate sustainability policies and management systems	Internal communication and information flows
	All	Education and training programs for employees (sustainability related and other programs)	
	All	Internal employee satisfaction and participation in decision making	
	All	Labor practices (SA 8000, fair labor code of conduct, and ILO's Decent Work standard)	
	All	Freedom of speech and open information in firm	
	All	Firm's impact and involvement in local and global community through production, usage, and EOL scenarios	
	All	Commitment to transparency in firm decision making	
	All	Commitment to avoid bribery and corruption, as well as securing transparency regarding political contributions	
	All	Philanthropy activities including engagement in community and sponsoring of organizations or events	

Stakeholder group	Life cycle stage	Description of sustainability information element ("information on….")	Accessibility
Internal Stakeholders	All	Commitment to advertising norms, i.e. responsible marketing (e.g. greenwashing, not provide damaging offers)	
	All	Commitment to honesty, trust, respect, and fairness in business relations (fair pricing and competition)	
	All	CSR or green activities giving average positive profit margins (not above or below average)	
	All	Firm's contribution to internal population shifts from rural to urban areas	
	All	Adherence to sustainability-labeling (e.g. EU Flower, EU Energy Label, Nordic Swan, German Blue Angels, Forest Stewardship Council, Marine Stewardship Council, Fair Trade, Energy Star, etc.)	
	All	Adherence to sustainability standards (e.g. ISO 14000-series)	
	All	Involvement and sharing of product environmental responsibility with suppliers	
	All	Contribution to internal population shifts (e.g. from rural to urban areas)	
	All	Adherence to the UN Human Rights Declaration	
	All	Direct and indirect employment in developing countries	
	All	Support of oppressive regimes	
	Materials	Commitment to sustainable supply chain practices	
	Materials, Manufacturing	Use and volume of hazardous substances, reusable or recyclable materials, or unsustainable materials in the product or in packaging	
	Manufacturing	Commitment to use effective environmental accounting systems and management tools with performance indicators (e.g. TBL accounting, LCA, EPD, GRI)	
	Manufacturing	Impacts on local natural resources, land, and biodiversity at production facilities	
	Manufacturing	Energy use (non-efficient, non-renewable and non-sustainable sources of energy), or commitment to energy saving projects	
	Manufacturing	Firm discharge permits and permits applications	
	Manufacturing	Investments in sustainable technologies	
	Manufacturing	Excessive generation of waste from manufacturing processes, including scrap products	
	Transportation	Frameworks for reusable or recyclable packaging/containers for transportation of goods	
	Transportation	Location (distance) and means of transportation of products (water, rail, road, air)	

Stakeholder group	Life cycle stage	Description of sustainability information element ("information on….")	Accessibility
	Use	Commitment to include service policies that are provided to the customer during the use phase of products (to improve eco-efficiency and prolonged life of product), and to provide product update policies to customers	
	Disposal	Motivational activities towards customers to promote recovery of products and components for reuse, recycling, or treatment/disposal, and to keep records of and track where the firm's products are (EOL instructions)	

13. Results – Exploring sustainability information implementation

This section builds on and elaborates on the results from Article 4 (Aschehoug and Boks 2011). Sustainability information implementation has not been the main focal area in this thesis. However, the present section presents the results from semi-structured group interviews conducted within SitComA and SitComB autumn 2011 and compares the results to those reported in Article 4. Three employees in SitComA and SitComB respectively participated from both firms. The group interviews lasted for three hours in SitComA and six hours in SitComB.

As in Article 4, the term implementation is used broadly, as the process and activities necessary for the realization of sustainability information in product development and design, or more precisely, what firms need to do to facilitate the "use" information elements in their day to day activities. Use is in this context further denoted as the process firms apply to gather and interpret information, or build knowledge based on such information.

The main results from the brainwriting workshop in the automotive supplier industry were used as the starting point for the group interviews in the furniture industry. These success criteria confirmed to a great extent, earlier findings of Johansson and Boks (Johansson 2002, Boks 2006), although their focus was predominantly green and focused on success factors and obstacles for ecodesign integration in product development. The majority of articles reported in their research have in common that they focus on integration or implementation of "something" into product development and design. Due to the many similarities between the success criteria (Aschehoug and Boks 2011) and success factors reported (Johansson 2002, Boks 2006), another brainwriting session within the furniture industry to develop additional success criteria was not considered beneficial. Instead, the previous results as presented in Table 13-1 were used to guide the interviews in SitComA and SitComB. Column 2-5 indicates to which extent the firms agree on the success criteria for sustainability information implementation or not.

Table 13-1: Success criteria for sustainability information implementation

Success criteria	AutoComA	AutoComB	SitComA	SitComB
-The use of sustainability information must be driven by management commitment.	X	X	X	X
-The use of sustainability information must be linked to economic performance and shareholder value within the firm.	X	X	X	X
-The use of sustainability information must be driven by (new) stricter regulations from public authorities.	X	X		
-Academia must be a driving force in the use of	X	X		

Success criteria	AutoComA	AutoComB	SitComA	SitComB
sustainability information by passing on and communicating information and new developments within research and up-coming requirements relevant to product development.				
-The use of sustainability information must be driven by customer demands and requirements.	X	X		
-The use of sustainability information must be driven by the establishment of an in-firm task force for sustainability issues.	X	X	(X)	X
-The use of sustainability information must be driven by the establishment of a task force for sustainable development within the industrial cluster for exchange of experience and knowledge.	X	X		X
-The use of sustainability information must be integrated in existing internal procedures and work processes.	X	X	(X)	X
-The successful use of sustainability information is dependent on high internal competence on sustainability issues.	X	X	X	X

All four firms emphasized *management commitment* to be of highest importance when introducing something new to organizations, regardless of what is being introduced. Both industries pinpointed in the interviews that what management does on a day-to-day basis, not what management says, becomes the accepted norm in the firms. In the automotive supplier industry, the will and determination on management level to invest in sustainable solutions was reported as important in this respect, for example by giving product designers time to invest to collect relevant sustainability information. It was also reported as important to link sustainable product improvements to the firms' continuous improvement activities. Continuous improvement activities are the backbone in the automotive industry. Therefore, linking sustainable product improvements to such activities ensures attention and follow-up.

In the furniture industry, the most profound challenges on management level were reported to concern balancing the triple bottom line in day-to-day decisions. For example, SitComA and SitComB themselves would like to use more sustainable materials based on sustainability information relating to raw materials, however, their customers are locked into habits which hamper such transitions. If the materials were changed, the firms fear the potential customer loss would mean that the firms would cease to exist. Hence, long-term development work was reported to focus on phasing out unsustainable materials and simultaneously influencing and changing customers' preferences for such.

Linking the "use" of sustainability information to *economic performance* and shareholder value was further emphasized as an important means of keeping management focus by all four firms. Literature suggests that sustainability may create financial value for a firm through increased sales due to improved firm reputation, and lowered costs due to process and product improvements (Epstein 2008). As such, performance indicators clearly linking economic value to sustainable product improvements may be important to firms

AutoComA and AutoComB emphasized that they would wait for more *customer requirements or governmental regulations* before they would take more sustainability information into consideration in their development activities. Today, some sustainability information is already used to build knowledge in the automotive supplier industry, dominantly as information forwarded through detailed customer requirements from the car makers. Presently, AutoComA and AutoComB are not willing to go beyond these, or to go beyond governmental regulations. The furniture industry expressed a different attitude and was correspondingly clear about being proactive; they aim to be in the driver's seat when it comes to sustainable product improvements. The furniture firms reported having invested significant resources in developing more sustainable products, although such products are not yet in demand among most customers. However, both furniture firms hope that current investments will be a future competitive advantage. As previously discussed in this research project, sustainability may be one way for firms to add new meaning to products as described by Verganti (Verganti 2009), and thus enhance firm competitiveness beyond the traditional aspects of functionality, cost, and quality. By viewing sustainability issues as a hindrance rather than a competitive advantage, the automotive supplier industry may miss the opportunity of adding value to their products through new product meaning.

All four case firms have previous experience in *collaborating with academia* on various development projects, including research. The automotive supplier industry expressed that they find it increasingly difficult to keep up to date with sustainability information on new regulations, and more importantly, to keep track of existing regulations and their corresponding implications. As a result, they would prefer academia to take a more active role in the future to collect sustainability information from the governmental domain for them. The furniture industry on the other hand considered sustainability information collection to be an in-house task to be led by the environmental management function. This is the way SitComA handles this issue today, and the way SitComB aims to deal with this issue in the future. Differences like the environmental manager's role and involvement in product development and design is suggested to account for the difference concerning academia role as information agent. The environmental manager in SitComA has an established role today in passing on information and in participating in development

activities. As opposed to the automotive suppliers', SitComA explained during the interviews that they regard academia more as a source of inspiration, than a driving force.

The automotive suppliers, in addition to SitComB, all agreed upon the potential usefulness of establishing an *in-house task force* for sustainability issues to drive the implementation of sustainability information. Especially in a start-up phase, a task force was suggested to be useful to ensure necessary attention and support, but also to give practical assistance in development projects. In SitComA, the use of interdisciplinary acquisition teams provide for the sharing of information today, in the form of a task force, whereas SitComB is in the start-up phase for establishing such teams.

An important issue is whether sustainability information implementation should be integrated into *existing work processes and procedures*, or can be done as a relatively separate activity. During the workshop and interviews in the automotive supplier industry, AutoComA and AutoComB argued that the customized information framework could be integrated into for example check lists for early design reviews as a means for checking if they have the necessary information to base their decisions upon. Integration into Design Failure Mode and Effects Analysis (DFMEA) was also mentioned as a possibility. SitComB also agreed that implementation into existing procedures would be a good idea; but that their first priority would be to make existing tools for product environmental improvements in SitComB function better than today.

The situation was slightly different in SitComA in which the potential benefits of exploiting more sustainability information through integration into existing procedures or work practices were considered small. Not because the sustainability information is regarded unimportant, but mainly because the information considered important, already to a great extent, is exploited in development activities. SitComA reported to have organization and infra-structure infrastructure which allows for systematic information identification, collection, and dissemination of such information throughout the organization. SitComA's adherence to a great variety of sustainability standards (e.g. ISO 14001, 14024, 14025, Green guard label, Certificate for guaranteed renewable energy use, Ethical Trade Initiative Norway, and SA 8000) may explain their current interest in, and use of sustainability information today.

All four firms emphasized *sustainability competence* and knowledge as important preconditions when implementing sustainability information in product development and design. The use of "sustainability champions" with special education and training to help co-workers in their sustainability work was suggested by the interviewees in the automotive

supplier industry, in addition to SitComB. This measure was reported already implemented and working in SitComA in which the environmental manager functions as a "champion" and supports the rest of the organization with information on sustainability issues. An important principle in SitComA, however, is that the responsibility for sustainability changes and improvements lies within each management level and not with the environmental manager.

SitComA pointed out an important aspect relating to sustainability competence that concerns personal motivation and beliefs on sustainability issues. Although SitComA consider sustainability competence and training to be adequate within the organization, they find that employees' motivation influences how they react and respond to sustainability information. During supplier audits for instance, some purchasers will search more actively for sustainability information and act upon it. Others will be satisfied to fulfill minimum requirements and thus be more reluctant to search for and act upon such information. As discussed in the article of Nonaka (Nonaka 1994), individuals within an organization will constantly work to recreate and understand reality according to their own personal goals and beliefs. This emphasizes the importance of going beyond sustainability competence and training in organizations, to work with motivational issues and culture to promote sustainability information collection and exploitation.

Potential synergies from sustainability *information sharing within the same industries* were discussed with the case firms. Within the automotive supplier industry, the firms indicated that such information sharing would be both possible and useful. AutoComA and AutoComB manufacture highly specialized products for many of the same customers, but without being in direct competition. This situation enables sustainability information sharing. SitComB also welcomed information sharing within their industry segments. SitComB completely dominates their product segment, and look upon themselves as guiding stars for other firms within this segment. They consider helping other firms elevating their sustainable performance as an issue of social and ethical responsibility. SitComA on the other hand, did not see the potential benefits of sharing sustainability information within their product segment. One reason being their environmental dominance for decades, they have little to learn from others. A perhaps more important reason is the competition situation within their product segment. SitComA does not dominate their product segment completely as do SitComB, and is hence more vulnerable to competition. Consequently, information sharing is regarded as less appealing.

Product development and design is an interdisciplinary activity which requires contributions from many functions (Andreasen and Hein 1986). In most firms, product

development and design are run as projects with multifunctional and interdisciplinary teams *(Andreasen and Hein 1986, Luttropp and Lagerstedt 2006, Cross 2008),* as no single designer have all necessary competence on design, sustainability issues, production planning, purchasing, logistics or marketing. All four case firms emphasized the importance of *interdisciplinary teams* to enhance sustainability information sharing between in-house functions.

Interdisciplinary teams were also emphasized as an important precondition for synergies in relation to sustainability information "use". Synergy effects may arise when several sustainability information elements from the same stakeholder or sustainability information from several stakeholders are combined, rather than seen as elements separate or isolated entities. Such synergy effects may be difficult to identify, measure, or describe due to their intangible nature. In the case studies, the interviewees were asked to provide more specific examples on information elements that combined exceed the sum of the individual elements. The majority of the interviews could not provide an answer to this question. The answers, or lack of answers, suggest that synergies are a difficult topic to comprehend which again might be linked to the intangible nature of synergy effects. Instead, a more general approach to synergies were described by the firms; in the early phases of product development, when interdisciplinary teams work together, each team member brings some sustainability information into the group, and by working together, this information is shared and exploited synergistically.

Concluding this section, success criteria for implementation of sustainability information in product development and design are suggested to be related to current use and experience with sustainability information. SitComA which reported to already use such information extensively throughout the organization to build knowledge, was also the firm that regarded least criteria to be important or relevant than the other firms. Based on the results, it is proposed that sustainability information implementation may be most beneficial to firms that only to a limited extent exploit such information to today (AutoComA, AutoComB, and SitComB). Firms that already exploit such information in their development activities (SitComA) may on the other side benefit more from motivational measures on individual level to promote more active collection of sustainability information.

Sustainability information sharing within industries may further be related to the competition situation within a product segments. Firms that were not in direct competition to others were in general found to be more favorable to such information sharing. Within firms, information sharing was proposed to be most in the early phases of product development in the form of interdisciplinary teams working together. Moreover, such teams provide for the opportunity for information to be exploited synergistically.

Part III: Supplementary information and theory

Appendix A: State-of-the-art on sustainability information

Based on the initial literature review, little research explicitly examining information in product development and design was identified. Baumann et al.'s (Baumann et al. 2002) important work of mapping of the green product development field was based on the idea that the development of a green product is a process within a firm, which in turn is embedded in a product chain, as well as in society. Baumann et al. argue strongly for the systems perspective in product development, meaning it is insufficient to deal with environmental problems and issues on the level of a single firm. To make real optimizations, the larger context of product development must to be considered. Finally, they conclude that environmental information systems need to be developed and used, as the information required for product development is found among different actors in the system, and that the "*…current information exchange is incomplete"*.

One of the most comprehensive frameworks on sustainability issues identified in literature is found in the works of Waage et al. (Waage et al. 2005). They propose a decision-making model for strategic sustainable development, a model that is synthesized and expanded from existing work within the field. This model is divided into several layers: strategies, actions, criteria, characteristics, and a tool box, and offers a pathway for decision makers wanting to integrate sustainability factors in decision-making, including product development and design. Concluding, they argue that data (and other information) required for many of the assessment areas, are "*…either unavailable, costly, or unverified*".

Le Pochat et al. (Le Pochat et al. 2007) argues for the necessity of "*…setting up new information flows"* in order to carry out ecodesign activities. In this respect, they also propose which departments within a firm should be involved. The purchasing department should be responsible for acquiring information from suppliers on parts and components. The logistics department should provide data (and other information) concerning product logistics at time of delivery. The marketing department should provide information on the marketability of the product, as well as inform the customer what to do with the product at its end of life.

Lofthouse (Lofthouse 2006) presents the typical problems product designers face when involved in ecodesign and what kind of support they need to enable them to engage in ecodesign projects. In that study, industrial designers indicated that they were unaware of where to look for ecodesign information, and that there were little guidance as to "*…where industrial designers could source such information".* The resulting information/inspiration tool provides environmental information concerning a product's life cycle (materials,

distribution, use, optimal life, end of life), in addition to information from stakeholders like the government (legislation, e.g. EC directives) and NGOs (eco-labeling information).

Lindahl's (Lindahl 2006) approach was also to identify requirements for design for environment methods and tools. Based on interviews with designers, it was found that a common obstacle in design for environment methods and tools was too comprehensive requirements for data. The designers claimed such information must be gathered before it could be used in tools and methods. Although Lindahl does not provide specific information examples of data or information as such, the study highlights the importance of having "*…access to information"* in product development and design.

Foster and Green (Foster and Green 2000) report the results from a study on how green issues influence the research and development (R&D) process as a contributor to innovation. In their article, they argue that the flow of green information and signals between different actors in a system may be more important than the actual links between them. In their idealized business model, information on environmental issues flows from external expertise like universities, NGOs, and consultants to the R&D function of the firm, end-user requirements flow either directly or indirectly to R&D from the marketing and sales function, and information from regulators (and other stakeholders) flow to the firm via the environmental management function. Their findings suggest that information flows on green issues are less direct than flows of other signals like performance requirements, and that the R&D function seldom has a close link to other sources of information, internally and externally. The information that reaches the R&D function is both *"...patchy"* and depends on the problem at hand (Foster and Green 2000). They conclude that *"...actively identifying, even seeking out input and information about green issues from customers, suppliers and other relevant stakeholders may well be the best way to make the innovation process greener"*.

Carlson et al. (Carlson et al. 2001) exemplify environmental information as environmental and quality standards, mostly the ISO 14000 family of standards and EMAS, national and international environmental legislation and regulations, environmental customer demands that can support the purchasing function in a firm, and environmental benchmarking within the business. In addition, environmental records and communication forms like policies, goals, and results from environmental assessments and audits are described as environmental information. Finally, environmental product declarations and information brochures for customers, environmental accounts and diagrams etc., are reported to be within the scope of environmental information.

Maxwell et al. (Maxwell and van der Vorst 2003, Maxwell et al. 2006) have developed a Sustainable Product and/or service Development (SPSD) approach which provides strategies for maximizing the environmental and social performance of all types of products and services. In the SPSD, supporting material is also provided, which includes some sustainability information examples: a sustainable products/services database of information resources, legislative compliance obligations, voluntary standards, and eco-labeling specifications, information from supply chain firms, and data of alternatives from existing data sources.

Forza and Salvador (Forza and Salvador 2001) discuss the importance of improving information flows with respect to product development because of the direct impact it has on design quality, but also on time to market. The article does not provide a definition or explanation on what information is, but provides examples of what it could be. These are customer information generated through marketing research, field service personnel feedback, sales personnel, direct involvement of customer in the specification phase, etc. They also point out that external information flows are expected to play an increasingly important role in the future, through increased use of customer information, but also in the context of the supply chain.

In the sustainable product design model by Haworth and Hadfield (Howarth and Hadfield 2006), several sources of information relevant to product development are presented. These are legal requirements from the EC directives, environmental, ethical, and sustainable development reports, as well as internal firm information on corporate social responsibility. Moreover, this model points out the importance of understanding stakeholder views and concerns by assessing risks in relation to the product.

Yet another body of research literature examines the sustainability information flow from the firms to its relevant stakeholders (consumers, investors, NGOs, and governments) with the purpose of enabling the stakeholders to make informed choices that reward corporate sustainability information leadership (Moffat and Auer 2006). Such information is seldom defined explicitly; however, information examples are frequently given. These may be Global Reporting Initiative (GRI) (Gallego 2006, Moffat and Auer 2006, Brown et al. 2009, Morhardt 2010), firm-specific reporting guidelines that assist firms in their sustainability reporting (Moffat and Auer 2006), or new suggestions on sustainability indicators for reporting purposes (Olsthoorn et al. 2001, Jasch and Lavicka 2006, Nordheim and Barrasso 2007, O'Connor and Spangenberg 2008).

Although definitions on sustainability information were not identified, many examples of what sustainability information could be were provided through articles mainly concerning social and environmental disclosure (Larsen 2000, Frieder 2002, Line et al. 2002, McMurtrie 2005, Moffat and Auer 2006, Brown et al. 2009, Prado-Lorenzo et al. 2009, Tagesson et al. 2009). Social and environmental disclosure covers information transfer from a firm to its relevant stakeholders, the opposite information flow direction than that of our scope of work.

Other researchers focus more on environmental information integration into IT-systems and how IT-systems can be designed for efficient management of environmental information (Carlson and Pålsson 2001, Frysinger 2001, Isenmann et al. 2007). In some of these articles, environmental information is not defined, only described in vague terms (Carlson and Pålsson 2001, Frysinger 2001), or examples are given of what could be handled in the IT-systems (Isenmann et al. 2007).

The most comprehensive information framework identified in research literature is presented by Erlandsson and Tillman (Erlandsson and Tillman 2009) who developed a framework for corporate environmental information collection, management, and communication. Erlandsson and Tillman argue that products are frequently placed on the marked with little environmental information, or inadequate information that can not be used for decision-making. Moreover, such environmental information is required by governmental bodies and market actors to minimize environmental impacts from production processes and products. Their framework for environmental information sorts out what corporate environmental information is, and also examines stakeholders as influencing factors. The main purpose of their framework is to support further research and studies on what shapes the environmental information flow in product chains and firms.

In a study focusing on knowledge acquisition and environmental commitment in SMEs, specific information sources that should be considered when building a knowledge network for environmental matters are studied (Roy and Thérin 2008). The results suggest the firms acquire environmental knowledge mainly from customers, but also consultants, suppliers, research labs and universities, competitors and public agencies were all considered possible sources of knowledge.

A recent article by Bos-Brouwers focuses on corporate sustainability and innovation in SMEs (Bos-Brouwers 2009). Typical stakeholders that are common to cooperate with in the context of innovation activities are listed. Customers and suppliers were listed as the stakeholders that are most common to cooperate with. As SMEs often come short in

knowledge, it is argued that such knowledge can be extracted from knowledge institutions, the government, trade associations, knowledge networks, design companies, peers, and consultancy firms.

Carlson et al.'s system for Integrated Business Environmental Information Management (IBEIM) supports and integrates information management for Environmental Management Systems (EMS), LCA and other Design for Environment (DfE) tools (Carlson et al. 2001). The system is based on supply chain information management, meaning that the system is open for information exchange between customers and suppliers. Seuring also argues that firms (actors) involved in environmental management are embedded in an environment where stakeholders are important (Seuring 2004b).

The importance of stakeholders is also highlighted by Alniacik et al. who argue that stakeholders are vital to modern business success (Alniacik et al. 2010). Given a highly competitive business world, attracting high quality employees and investors is just as important as tending to customers. Global competition makes it important for firms to go beyond the traditional physical assets and also integrate more intangible assets like image, reputation, and perceived goodwill to gain a competitive advantage. As such, the incorporation of sustainability into all business processes, including product development and design, will be important for long-term growth and success (Alniacik et al. 2010).

Based on this state-of-the-art review, an important gap in extant research literature was identified within the field of sustainability information relevant to product development and design. In the reviewed articles, there is a lot of talk about information; however, most researchers only indicate the importance of information in relation to product development. Except for Erlandsson and Tillmann (Erlandsson and Tillman 2009), and Foster and Green (Foster and Green 2000), few attempts have been made to identify or clarify what such information could be. In addition, the terms information and data are often used interchangeably, and there is a predominance of literature describing sustainability related product and process related data, not information. The context in which the information and other data are intended for is sometimes missing or unclear. None of the reviewed articles included a definition on sustainability information relevant to product development and design. Finally, an important finding is the predominance of literature describing stakeholders in relation to such information flows. This indicates that stakeholders could be a viable approach for identifying, collecting, and compiling sustainability information. Hence, based on this initial review, a contribution to the general body of knowledge can be made in this research project by answering the earlier formulated research questions.

Appendix B: Research methodology

Research may be defined as the creation and development of knowledge, where the output is contribution to knowledge (Karlsson 2009). Wikipedia, defines research as a scientific search for knowledge in order to establish new facts, solve new or existing problems, prove new ideas, or develop new theories (Wikipedia 2011). Other definitions include investigation aimed at the discovery and interpretation of (new) facts, revision of already accepted theories and laws, or practical application of such new theories or laws (Merriam-Webster 2011b). The Norwegian Research Council describes the purpose of research as generating more insight and promoting scientific and knowledge-related development (Reserach-Council 2011).

A researcher may further be described as somebody who consciously investigates something to either disqualify existing knowledge, confirm existing knowledge, or contribute to enlarging it in a critical, conscious, and insightful way (Arbnor and Bjerke 2009). Summarized, research is about acquiring and generating new knowledge (knowledge creation), based on the works of previous researchers.

B.1 Explaining methodology

Methodology is a set of methods, rules, or ideas that are important in science (Merriam-Webster 2011a). It is both a way of thinking and of acting. It contains a number of concepts, which describe steps and their relations, which are required in the process of creating new knowledge. Methodological approaches make certain **assumptions** about reality. These assumptions become a guide for how knowledge is created. Such assumptions may vary from researcher to researcher, and impact how problems, techniques, and knowledge are viewed in general (Arbnor and Bjerke 2009).

The relations between assumptions and methodological views are studied in the field of **theory of science**. In this field, a conceptual language has been developed to bridge the relations between assumptions and methodological views (Arbnor and Bjerke 2009). The latter is also described as a **paradigm**. According to Törnebohm, a social science paradigm can be described as containing the following components (Törnebohm 1974):

- A conception of reality: how reality is constructed, e.g. is it ordered and logical, or is it chaotic, or is it both ordered and disordered.
- A conception of science: what kind of knowledge that is gained through the researcher's education, as this will affect the concepts, beliefs, and knowledge interests.

- A scientific ideal: which is related to the researcher as a person, e.g. does the researcher look upon himself/herself as being guided by the idea that science is objective and not influenced by interests, or does the researcher claim to be partial.
- Ethical and aesthetical aspects: is about what the researcher claims being morally suitable or unsuitable, e.g. observing people should not be done without their consent.

Hence, disagreement with one of these components will most likely result in a different paradigm, for example Kuhn's paradigm which is more closely related to natural science (Kuhn 1970).

Similarly, there is an **operative paradigm** to bridge the relations between methodological views and the study/research area. The operative paradigm deals with practical issues like research plans, units of analysis, techniques for collecting data, etc. When developing an operative paradigm, methodical procedures and methodics are developed and created (Arbnor and Bjerke 2009).

A **methodical procedure** can be described as how researchers arrange, develop, and modify techniques based on methodological views. A technique is the way creating knowledge is carried out like a personal interview. **Methodics** may further be described as how the study is actually approached, planned, and conducted (Arbnor and Bjerke 2009).

To depict all the described concepts that influence methodology Arbnor and Bjerke have created a model describing the guiding principles for creating knowledge, Figure B-1 (Arbnor and Bjerke 2009). These principles must fit the research area and the ultimate presumptions held by the researcher.

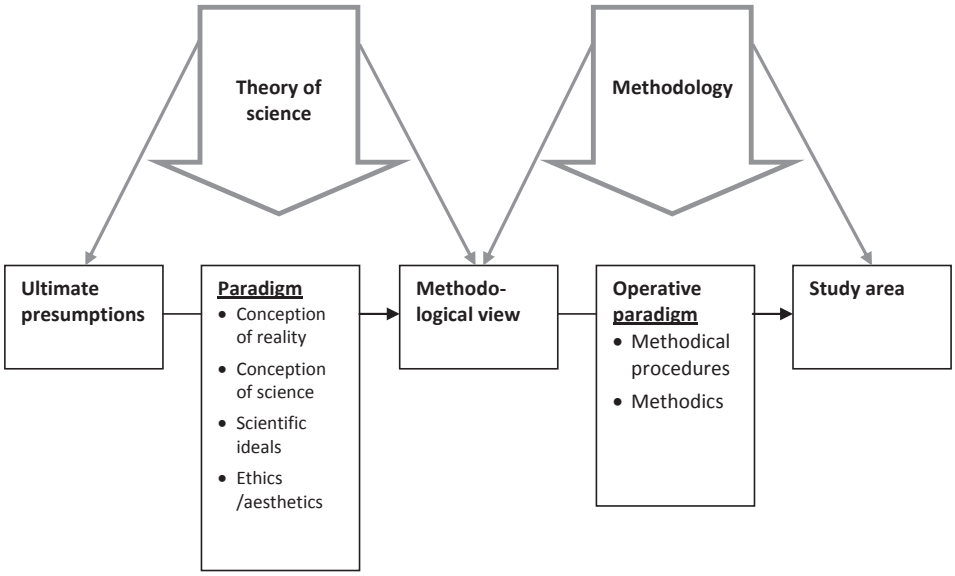


Figure B-1: Theory of science and methodology (Arbnor and Bjerke 2009)

B.2 Methodological views and perspectives

There is no ranking of the "best" methodology view; it is rather about finding the methodology perspective that best fits the assumptions held by the researcher. Arbnor and Bjerke have classified three main methodological views, the analytical view, the systems view, and the actors view as demonstrated in Figure B-2 on the next page.

The **analytical** view aims to explain reality. This reality is mostly based on summative objective and subjective facts, where parts can be regarded in isolation from other parts. The analytical view typically includes mathematicians, chemists, and physicist, but also social scientists may belong here. An important concept is the hypothesis, in which possible fictive patterns are either falsified or verified as causal relations through surveys or representative cases. A typical research hypothesis within the analytical view for this research project could be: *firms that exploit sustainability information in product development will develop more sustainable products than firms that do not.* Within the

analytical view, this hypothesis could be tested and verified/falsified by eliminating various influencing factors.

Within the **actors** view, the objective is to understand how social reality is defined, constructed, and maintained. The models in the actors view constitute reality, not only represents it. Moreover, the creation of knowledge is performed in dialogues with the actors in the research area. The researcher becomes part of the process through action. A typical actor's view research project within this particular project could be to study the implementation and use of sustainability information to build knowledge and awareness in product development and design, by being part of the actual implementation process in the particular firm.

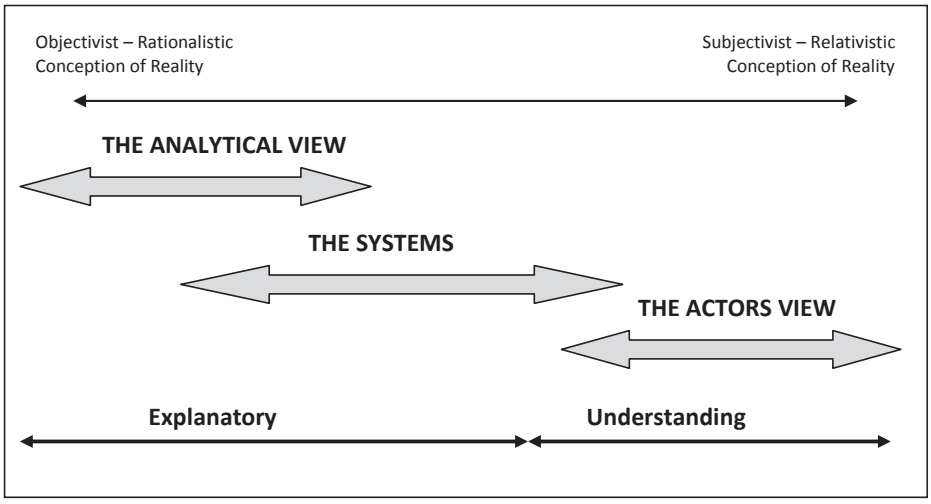


Figure B-2 : Explanatory and understanding knowledge (Arbnor and Bjerke 2009)

In the middle lies the **systems** view which aims either to explain or understand reality. The systems view looks at reality as full of facts, but where the various parts can not be seen in isolation from each other, but more as structured wholes, i.e. systems. Knowledge within the systems view is typically created through typical cases or partly unique cases. The systems view is grounded on systems theory, holism, and structuralism (Arbnor and Bjerke 2009). An explanation of how this present research project relates to systems view have been explained in Section 3.1

B.3 Case research and case studies

Case research is a method that uses case studies as its basis (Karlsson 2009). It is an excellent means of studying emergent practices, products, customer involvement, or quality information (Finch 1999), and is considered particularly good for examining how and why questions (Yin 2009). According to Meredith (Meredith 1998), the main strengths of case research are:

- The phenomenon can be studied in a natural setting and theory can be generated from observing and understanding actual practice.
- Case research can be used to explore the questions of why, what, and how.
- Case research lends itself to early, exploratory investigations where the variables are unknown and the phenomena not completely understood.

Obstacles or challenges associated with case research are the time needed to perform the studies (time consuming), and the requirement for skilled interviewers. Furthermore, caution is needed when conclusions are drawn from a limited set of cases (Voss et al. 2002).

Case studies are the units of analysis in case research and are in general considered useful for different types of research like exploration, theory building, theory testing, or theory extension. Table B-1 summarizes purpose, research questions, and methodology for case studies (Voss et al. 2002):

Table B-1: Matching research purpose with methodology (Voss et al. 2002)

Purpose	Research question	Research structure
Exploration: Uncover areas for research and theory development.	Is there something interesting enough to justify research?	In-depth case studies. Unfocused, longitudinal field studies.
Theory building: Identify/describe key variables. Identify linkages between variables. Identify why these relationships exist.	What are the key variables? What are the patterns or linkages between variables? Why should these relationships exist?	Few but focused case studies. In depth field studies. Multi-site case studies. Best-in-class case studies.
Theory testing: Test the theories developed in the previous stages. Predict future outcomes.	Are the theories generated able to survive the test of empirical data? Did we get the behavior predicted by the theory or did we observe another unanticipated behavior?	Experiment. Quasi-experiment. Multiple case studies. Large scale sample of population.

Purpose	Research question	Research structure
Theory extension/refinement: To better structure the theories in light of observed results.	How generalizable is the theory? Where does the theory apply?	Experiment. Quasi-experiment. Case studies. Large scale sample of population.

The case study or the unit of analysis is very much dependent on the research question and study area; consequently, the unit of analysis in this research project varies. In case studies based on a systems view, representativity in a statistical sense is not valid. Instead, the cases that are chosen should represent a certain type of systems. The starting point for this particular research project was a single case explorative study within a Norwegian manufacturing firm (Ref. Article 1), with one unit of analysis. It was important to choose a single case study as a start to learn if the research area was interesting enough to justify further research.

After the theoretical development of the sustainability information framework based on stakeholder theory, multiple case studies were chosen, investigating various conditions in relation to this framework in industrial practice. Findings from multiple case studies are often considered more robust, but the rationale for choosing single or multiple case studies are different (Yin 2009). One reason is resource constraints, in which the time and resources required to do multiple investigations might be too much for a single researcher. In multiple case studies, however, replication logic is important. Case studies were carried out in two firms in the Norwegian automotive supplier industry which potentially could predict similar results, a literal replication (Ref. Article 3). Another set of two cases was chosen within the Norwegian furniture industry, where potentially different results could be predicted, a theoretical replication, due to different business contexts (Ref. Article 5). Figure B-3 summarizes the case studies conducted as part of the present research project.

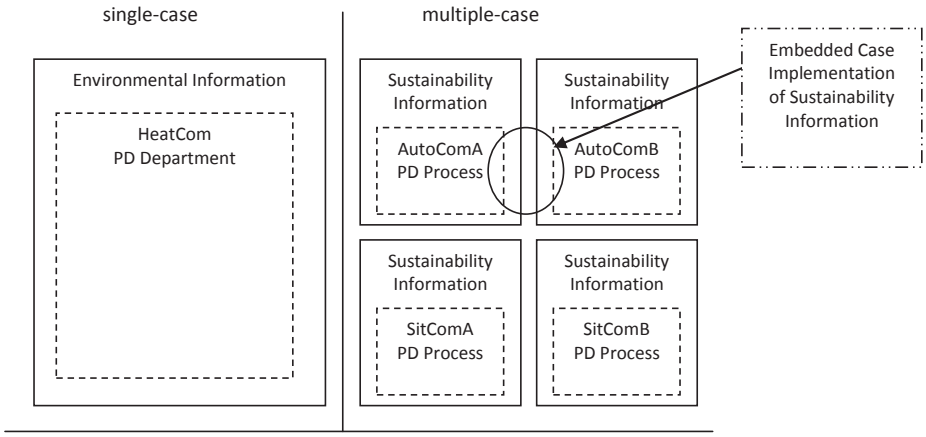


Figure B-3: Case research design adapted from (Yin 2009)

The first two case studies from the automotive supplier industry also included an embedded unit of analysis (Ref. Article 4), whereas the two cases from the furniture industry were holistic cases. The embedded unit of analysis concerned success criteria for the implementation and use of sustainability information in product development in the automotive supplier industry.

B.4 The operative paradigm

In order to plan the practicalities of the research, detailed research protocols were written in advance to explain the steps in the planned case studies. The research protocol represents **methodics** in reference to the presented Figure B-1. These were developed based on (Karlsson 2009),(Yin 2009), and (Arbnor and Bjerke 2009) and included a description of the following elements:

- Formulating research questions and defining the unit of analysis.
- Case selection and sampling.
- Pre-visit preparations.
- Techniques for collecting data (interviews, observations, etc.), including questions to be used in the interviews.
- Who should the respondents be? Who should be contacted?
- Triangulation, the use and combination of different methods to study the same phenomenon.
- Recording of data.

- Data documentation and coding.
- Analysis of data.
- Writing up the results.

There are different approaches to collecting data, based on the situation and the study area, which all are associated with different strengths and weaknesses which are portrayed in Table B-2 below (Yin 2009).

Table B-2: Source of data/evidence used in my research project based on (Yin 2009)

Type of data	**Strengths**	**Weaknesses**
Documentation	• Stable, can be reviewed • Unobtrusive - not created as a result of the case study • Exact - contains exact names, references, and details • Broad coverage - long time span, many events, many settings	• Retrievability - can be difficult to find • Biased selectively, if collection incomplete • Reporting bias - reflects bias of author • Access - may be deliberately withheld
Archival records	• Same as for documentation • Precise and usually quantitative	• Same as for documentation • Accessibility due to privacy reasons
Interviews	• Targeted - focuses directly on case study topics • Insightful - provides perceived causal inferences and explanations	• Bias due to poorly formulated questions • Response bias • Inaccuracies due to poor recall • Reflexivity - interviewee gives what the interviewer wants to hear
Observations	• Reality - covers events in real time • Contextual - covers context of “case”	• Time consuming • Selectivity, broad coverage difficult without a team of observers • Reflexivity - event may proceed differently because it is being observed • Cost - hours needed to observe

In this particular research project, different data collection techniques were used, dependent on the problem at hand, i.e. the research question, as shown in Figure B-4.

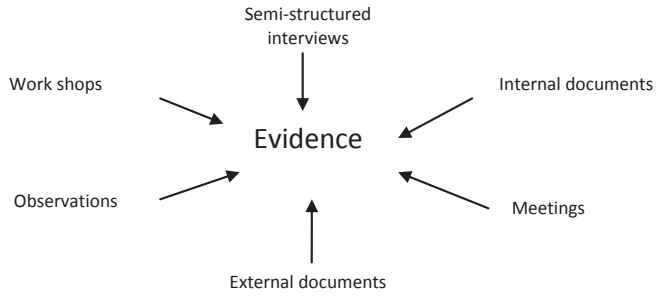


Figure B-4: Data collection techniques used in the research project

Semi-structured interviews: Interviews are a very common way of collecting information and are used extensively in the systems approach, most commonly personal interviews or face-to face interviews. In this research project, semi-structured face to face interviews were most commonly used, but also telephone interviews have been conducted. During the interviews, interview guides with both open and closed questions were used, dependent on the study area.

Meetings: Several meetings were conducted with the participating case firms. These meetings were mostly conducted to plan the research or to examine and discuss research results and findings. However, clarifying questions were asked during meetings, and as such new information was also retrieved during meetings. Moreover, observations of the groups could also be conducted during the meetings.

Observations: The situations of creating knowledge are in this case based on observing what happens in the present. In the present research project, observations in combination with interviews were used to observe how the interviewees reacted to different types of questions. In addition, observations were made during meetings, walk throughs, and workshops.

Documents: Both internal and public available documents were collected during the case studies. The documents were mostly used to gain background information on the firms, or to verify statements made by employees during interviews. Examples of documents used were public available annual reports, HSE-documents, CSR-documents, firm policies and goals, procedure descriptions, etc.

Workshop: One work shop was conducted as part of the embedded case in the automotive supplier industry. The work shop was chosen to gather as much information as possible from multiple informants on the same topic.

B.5 Writing up the data

There are different views on whether field notes should be recorded. Tape recordings provide accurate representation of what was actually said during the interviews, and are recommended where exactness of wording is very important. On the other hand, the time required to transcribe data from tape records makes the method less appealing. If the purpose of the interviews is more focused on the object of the data, what they represent, rather than the exact wording, then the benefits from tape recordings are reduced (Karlsson 2009). In the present research project, the object of the data was the main purpose of the interviews. Consequently, handwritten and typed field notes taken during interviews and observations were considered appropriate. As such notes written "on-the-go" usually contain only half the actual content, write-ups were written down after the interviews, as recommended in literature to fill in some of the missing information (Miles and Huberman 1994). The combination of field notes and write-ups were used as a basis for the analysis phase.

B.6 Analysis

Analyzing data from case studies is by many considered the most challenging phase in case studies. There are few cookbook recipes to guide inexperienced researchers, therefore, knowing what to look for is important. A good starting point, however, is to play around with the accumulated data in the beginning, by e.g. putting information into different types of arrays or creating displays (Yin 2009).

The first challenge of the analysis is usually the coding phase (Miles and Huberman 1994), which makes it easier to discover emerging trends. The codes are usually attached to "chunks" of information from words, phrases, or paragraphs. The codes are tags or labels for giving meaning to the information gathered. In this project, some information comes from structured, closed-ended questions, while other data come from open-ended questions.

The following list based on Bogdan and Biklen as described in (Miles and Huberman 1994) was used to guide the development:

1. Setting/context: General information on surroundings that allows you to put the study into a larger context.
2. Definition of the situation: how people understand, define, or perceive the setting or the topics on which the studies bear.
3. Perspectives: ways of thinking about their setting shared by informants ("how things are done here").
4. Ways of thinking about people and objects: understandings of each other, of outsiders, or objects in their world (more detailed than above).
5. Process: sequence of events, flows, transitions, and turning points, changes over time.
6. Activities: regularly occurring kinds of behavior.
7. Events: specific activities, especially ones occurring infrequently.
8. Strategies: ways of accomplishing things: people's tactics, methods, techniques for meeting their needs.
9. Relationships and social structure: unofficially defining patterns like as cliques, coalitions, romances, friendships, enemies.
10. Methods: problems, joys, dilemmas of the research process – often in relation to comments by observers.

Before starting interviews for the case studies, a "start list" of codes was developed, in addition to displays for analyzing the information. Different codes were prepared for each case study.

Relating to sustainability information importance and accessibility, an Ishikawa diagram or fishbone diagram (Andersen et al. 2008) was used as a display for analyzing the combined data from each case in studies 2, 3, 4, and 5. Low importance information and low accessibility information elements were assigned 1 point, and equivalent high importance and high accessibility information elements were assigned 2 points. The final results include the accumulated points from this analysis phase. Then, a more detailed display of presenting the results was created as shown in Figure B-5 for each relevant stakeholder group.

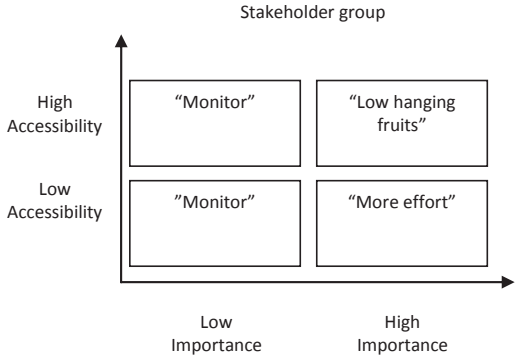


Figure B-5: Stakeholder display for analyzing sustainability information elements for case studies 2, 3, 4, and 5.

Supplementary data were gathered during the interviews for all the case studies, tables of arrays or matrix displays were used to further analyze the data, based on the coding. Patterns and themes were searched for and recorded in tables. In this phase it was important to ask the question "why?" multiple times in order to explain the emerging results. In the explanation building phase, propositions related to the research questions were developed as described in Miles and Huberman (Miles and Huberman 1994). Propositions were then clustered thematically, and evidence was sifted for each proposition and further categorized as strong, qualified, neutral, or contradictive. Based on this process, propositions were confirmed, dismissed, or reformulated.

Finally, rival explanations for relevant propositions were developed to enhance creative thinking, but also to investigate contradictive arguments that might be just as true as the initial explanations. To develop rival explanations, the template provided by (Yin 2009) in the Table B-3 was used to guide the process:

Table B-3: Different types of rival explanations (Yin 2009)

Type of rival	**Description**
The null "hypothesis"	The observation is the result of chance circumstances only
Threats to validity	e.g. history, maturations, testing, instrumentation
Investigator's bias	"Experimenter effect", reactivity in field research
Direct rival	An intervention, other than the target intervention accounts for the results ("the butler did it")
Commingled rival	Other intervention and the target intervention both contributed to the results ("it wasn't only me")

Implementation rival	The implementation process, not the substantive intervention accounts for the results (“did we do it right?”)
Rival theory	A theory different from the original theory explains the results better
Super rival	A force larger than, but including the intervention, accounts for the results (“it is bigger than both of us”)
Societal rival	Social trends, not any particular force or intervention accounts for the results (“the times they are a-changing”)

In the present study, the process of gradually building explanations was conducted in an iterative manner to allow for revisions and reformulating explanations and propositions (Yin 2009). The final results were then presented in the articles attached to this thesis.

Appendix C: Exploring sustainability

Sustainable development in a historical perspective has roots back to the early sixties when concerns about the environment and society lead to Rachel Carson's book Silent Spring (1962) (Bhamra and Lofthouse 2007). In her book, Carson discussed how interfering with natural systems, though the use of the insecticide DDT, could have serious environmental consequences and effects on human health. Since the publishing of this seminal book, environmental and societal concerns have been steadily growing, as evidenced through the establishment of important nongovernmental organizations (NGOs) like Friends of the Earth and Greenpeace, the establishment of the United Nations Environmental Program, and the publication of the important Limits to growth (1972) by the Club of Rome (Bhamra and Lofthouse 2007). A great many initiatives followed before the historic report by the World Commission on Environment and Development (WCED), also called the Brundtland Report, titled Our Common Future (1987) (Bhamra and Lofthouse 2007). In that report the term "sustainable development" was first introduced and defined as "*…development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (UNEP 1987). This definition does not specifically mention the environment, but refers to the well-being of people as an environmental quality. Moreover, it introduces the ethical responsibility of the present generations to future generations. Our common future (1987) was soon to become an important document for two main reasons: 1) It brought into the public debate the responsibility we all have for the future. 2) It pinpointed that then current ideas of development were impossible to further (Vezzoli and Manzini 2008).

Later, this definition on sustainable development has earned some criticism for not being specific enough, and many scientists, researchers, and organizations have proposed new definitions over the years to make sustainable development more tangible, like the "Nine ways to achieve sustainability" mainly based on the economist view on sustainability (Rogers et al. 2008). This is also the starting point of Mohan Munasinghe's approach, an economist from the World Bank, that defines sustainable development as: "*1) Economic – maximizing income while maintaining a constant or increasing stock of capital, 2) Ecological – maintaining resilience and robustness of biological and physical systems, and 3) Social – Cultural – maintaining stability of social and cultural systems"* (Rogers et al. 2008). Yet, OECD defines sustainable development as *"equity today, environmental justice, intergenerational equity, and stewardship"* (Bhamra and Lofthouse 2007). The two perhaps most interesting contributions to this debate have been made by (Ehrenfeld 2008) and (Elkington 1998) as discussed in the following.

C.1 Sustainability by design

Sustainability according to John Ehrenfeld is more of a philosophy direction as described in Sustainability by design (Ehrenfeld 2008). Ehrenfeld defines sustainability as "*the possibility that human and other life will flourish on the planet forever"*. "Flourishing" in this context is the key to sustainability, as Ehrenfeld argues that we must move away from the modern way of "having" to the more flourishing way of "being". Flourishing concerns all natural systems, including humans but also other living systems. For us (humans), flourishing is about more than just staying healthy, it is also about quality of life, living a good life of dignity, justice, fairness, and equity. For other living species, flourishing embraces the survival and maintenance of the species. Flourishing can further be regarded as a metaphor, and as such enables everybody to reflect on what flourishing means to the world. The "forever" in the sustainability definition adds the timelessness and the responsibility we have for future generations. "Possibility" in this sense means bringing forth from nothingness something we desire to become present. In a sense, it enables us to visualize and strive for a future that is neither available nor present. Ehrenfeld further claims that without recovering our sense of "being" instead of "having", it will be almost impossible to take care of the world and produce flourishing.

According to Ehrenfeld, unsustainability comes from our modern lifestyles and can be considered an unintended effect. The root cause of unsustainability is in the way we try to solve every problem by the modernist frame of thinking, instead of shifting to more fundamental actions. Unsustainability is often real and tangible, and can be measured. Ehrenfeld argues that almost every action in the name of sustainable development has been an effort to reduce unsustainability. But as Ehrenfeld continues, reducing unsustainability, although important, will not create sustainability because sustainability is not the obverse of unsustainability. Sustainability can be regarded as an outcome of the way we live our lives and an emergent property of living systems, the highest set of human aspirations and associated cultural values.

Ehrenfeld describes that modern life and culture have affected human beings in three important ways as illustrated in Figure C-1: 1) The human domain, arising out of our (lost) sense of what it is to be a human being, 2) The natural domain, arising out of our (lost) sense of our place in the natural world, 3) The ethical domain, arising out of our (lost) sense of responsibility for our actions and relationships to others.

Thus, sustainability involves addressing these three domains simultaneously. The natural domain has emerged in public debate because of the obvious side effects modern lifestyles have on nature and the environment. The human domain relates to the flourishing

dimension and to become whole ourselves. The last domain, the ethical domain, is less apparent because modern technology has in many ways diminished our ability to be accountable for our own actions as the consequences are often displaced in time or space according to Ehrenfeld. Hence, unintended actions must be taken into account in design. Through design, the user can be guided towards what ought to be done in using the product. Sustainability in design is then about "*designing a world that brings forth flourishing into our everyday activities"*.

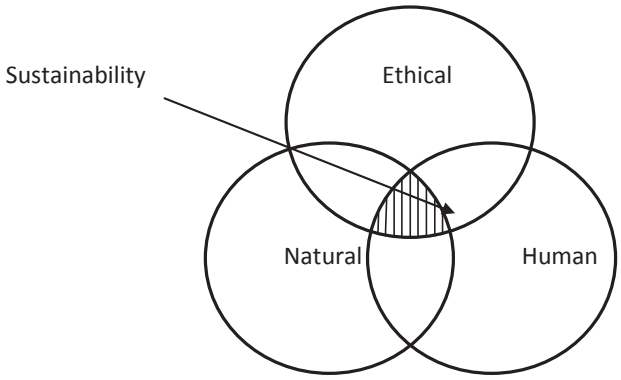


Figure C-1: Ehrenfeld's view on sustainability (Ehrenfeld 2008)

C.2 The triple bottom line (TBL) concept

A more down to earth view on sustainability was proposed by John Elkington as early as 1998 with the important Cannibals with forks (Elkington 1998). This book has influenced both the research community and practitioners. Elkington introduced the triple bottom line concept on sustainable development, according to which firms are required to change their performance towards the economic, social, and environmental bottom lines (also known as people, planet, profit) which are mutually interdependent on each other: "*society depends on the economy, the economy depends on the global ecosystem, whose health represents the ultimate bottom line*". The basic idea is taken from traditional business accounting, but in

addition, social and environmental aspects shall also be taken into account. The *economic* bottom line (profit) is about considering the traditional physical and financial capital; it's about accounting for this performance, and for accountability for long-term economic sustainability. The *environmental* (planet) bottom line concerns the understanding of the natural capital, i.e. considering which forms of natural capital (critical, renewable, replaceable, or substitutable) that will be affected by the planned business activities, and if the planned activities will affect the balance of nature. The environmental bottom line is also about long-term environmental sustainability. At last, the *social* bottom line (people) concerns human capital, but also society's health and overall wealth creation. It is about community relations, product safety, training initiatives, charity, and philanthropy.

As illustrated in Figure C-2 below, some of the most profound challenges are in the shear zones between the circles. Elkington argues that sustainable capitalism will require more than environmentally friendly technologies, eco-efficiency, environmental liability, and ecological taxes that are in the shear zone between the economic and environmental circles. Also environmental justice, carrying capacities, and environmental refugees will become increasingly important; these are all in the environmental and social shear zone. Equally important will radical new views on social equity, social impacts on investments, business ethics, fair trade, and human rights become, which are in the social and economic shear zones.

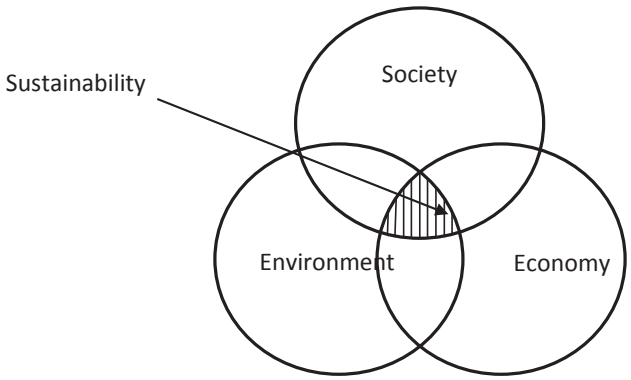


Figure C-2: Elkington's triple bottom line concept simplified

Elkington has also identified seven drivers or revolutions that are expected to transform the society at large to become more sustainable, which in turn will affect the way firms think about sustainability and sustainable product development.

Elkington describes that *markets* are increasingly expected to be driven by competition. Today, firms use competition as an excuse not to address sustainability. In the future, sustainability will be used as an important part of the business case for action and investment. Elkington further argues that there will be a worldwide shift in societal *values*, were a shift from "hard" commercial values to "soft" sustainability values will occur. The recent democracy wave in northern Africa is such an example, where people are fed up with the injustice of the sitting governments, and start to revolt. Equity, justice, and poverty are important drivers that will change societal values over time. Another revolution that will transform every day business, or already have, is the worldwide *transparency* revolution. Internet provides for opportunities like twitter, facebook, YouTube etc. where everyone can post messages, information and pictures about injustice, for example current environmental practices in firms, or harmful working conditions. The forth revolution is about *life-cycle technology*; where there is a shift from cradle to grave attitudes towards cradle too cradle thinking. New techniques to measure the sustainability performance of firms are being developed. At the same time emerging technologies (e.g. nano technologies) have the opportunity to change a lot of "given truths". New *partnerships* are the fifth revolution, especially untraditional partnerships between firms and campaigning groups. Instead of influencing the firm from the outside, the new partnerships provide environmental activists for instance, for the opportunity to influence firms from the inside through public-private partnerships. Yet another factor that will influence firms is the way we look at *time*. More and more happens every minute of the day, worldwide, as time becomes "wider". On the other side, sustainability pushes time to become "longer". A major challenge within the time frame is that most business leaders and politicians only think two to three years ahead, whereas sustainability requires thinking across several decades. Sustainability will require thinking simultaneously both on "wider" and "longer" time. The last driver described by Elkington is about the responsibility of the corporate board, *corporate governance*. Focus will change from purely economic goals to "what is the business for?", and "how do we balance shareholders and stakeholders?"

C.3 Design for sustainability

In the recent Design for Sustainability – A Step-by-Step Approach (2009) developed by the United Nations Environment Programme and Delft University of Technology, (United Nations Environment Programme 2009), sustainability is referred to as the social,

environmental, and economic elements, or the people, planet, and profit (PPP) approach. For a product to be sustainable, product development and design have to fit within different frameworks linked to PPP as demonstrated in Figure C-3.

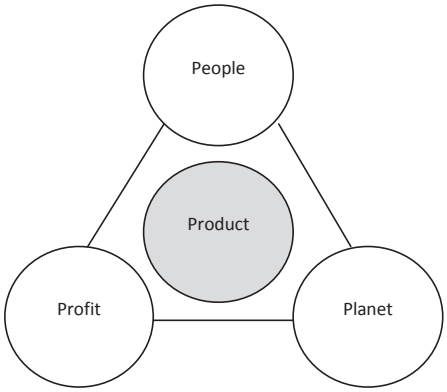


Figure C-3: People, profit, planet and product according to UNEP (United Nations Environment Programme 2009)

This approach builds on and elaborates on Elkington's triple bottom line concept, but is expanded into a more focused approach to products. The People aspect is about creating opportunities to meet social and equity requirements (e.g. improve working conditions, reduce income inequity, abolish child labor, reduce population growth, adapt international employment standards, and abolish large scale dislocation of people). The Planet aspect is about fitting within the carrying capacitates of supporting ecosystems (e.g. use of renewable energy, reducing use of toxics, stopping deforestation, soil loss, erosion, ecosystems destruction, and stopping overexploitation of renewable resources and water). The Profit aspect is about creating equitable values for customers and stakeholders along the global value chain (e.g. value for company stakeholders, fair business model, fair price for commodities and raw materials, and value for customers) (United Nations Environment Programme 2009).

It is highlighted that all PPP elements are not equally relevant to all firms, industries, or countries, and that not all firms or product development and design projects have equal capacities to take on the PPP elements. Nevertheless, firms are encouraged to review their

industry needs and identify aspects that could lead to maximum positive impacts (United Nations Environment Programme 2009).

Concluding this section, there is a jungle of definitions and approaches to sustainability and sustainable development available, and all have not been reviewed here. For the present research project, a pragmatic view on sustainability was taken in line with the systems view (Arbnor and Bjerke 2009) in which diffusion (easily recognized), simplicity, and ease of communication was considered important.

As a result, this research project adopted the triple bottom line concept of Elkington. In research literature, great many examples of the TBL approach are found, (e.g. (Robèrt et al. 2002, Hauschild et al. 2005, Karlsson and Luttropp 2006, Koplin et al. 2007, Seuring and Müller 2008, Tukker et al. 2008, Bos-Brouwers 2009, Linnenluecke et al. 2009, Moore and Manring 2009, Gold et al. 2010, Hallstedt et al. 2010)). In addition to the diffusion of this definition in research, the TBL concept comes across as easy to describe on a superior level (environmental, social, and economical). Finally, this definition also came across as more tangible than the more "airy" definition of Ehrenfeld, and consequently easier to use in communication with firms, interview objects, and other researchers. Since the present research project required repeated contacts with firms, a definition that was easy to describe and communicate was chosen.

Appendix D: Data, information, and knowledge

Data, information, and knowledge are important for all firms and organizations. "*The effective utilization of these "commodities" are increasingly the only way for organizations to achieve and sustain competitive advantage"* (Hicks et al. 2002). In product design and development specifically, the engineer uses many different sources of information. In fact, engineering rests heavily on information in order to carry out core activities. As a consequence, an improved product development process and better design will most likely be achieved through efficient use of information and knowledge. As a result, many firms have adopted traditional information or knowledge management systems. A key issue in this respect is what information should be captured and identified (Hicks et al. 2002).

In practice, also even in research, the constructs of information and knowledge are often used interchangeably, which is also the case with data and information. Many different definitions of data, information, and knowledge have been developed and proposed by researchers over the years (Nonaka 1994, Hicks et al. 2002, Braganza 2004, Zins 2007). It is consequently important to describe how these constructs are understood and used in the present research project as well as the relations between them, as they are important building blocks in this research.

D.1 The data-information-knowledge hierarchy

A popular way of describing data, information, and knowledge constructs is to say that data are the raw material of information, and information is the raw material of knowledge, although not all researchers agree with this concept (Nonaka 1994, Braganza 2004, Zins 2007). The traditional data-information-knowledge hierarchy as presented in Figure 5-1 has its roots in traditional IT-methods, according to which information is extracted from data, and knowledge is extracted from information (Braganza 2004).

Data are often regarded as the most basic descriptive elements representing a perception or measurement of an object, and are frequently described as lacking content, meaning, and intent (Uotila and Melkas 2007). Data may be described as the constituent elements of information (Braganza 2004). Data may be facts and observations (Braganza 2004), and may also be structured or unstructured (Hicks et al. 2002).

Information may be regarded as what people or systems need to be able to carry out work practices, and may encompass e.g. facts or propositions (Hicks et al. 2002, Braganza 2004). According to Nonaka (Nonaka 1994), information may loosely be regarded as a flow of messages. Nonaka has adapted this view from definitions proposed by Machlup (1983) and

Dretske (1981). Machlup's definition is referred to as; *"information is a flow of messages which might add to, restructure or change knowledge"*. Dretske's view on information is; "*information is that commodity capable of yielding knowledge, and what information a signal carries is what we can learn from it*". Hence, information is necessary for initiating and formalizing knowledge (Nonaka 1994). Although Nonaka describes a strong interdependency between information and knowledge, the data-information-knowledge hierarchy, where one is being extracted from the other as shown in Figure 5-1, is not part of the dynamic knowledge creation model proposed in that article.

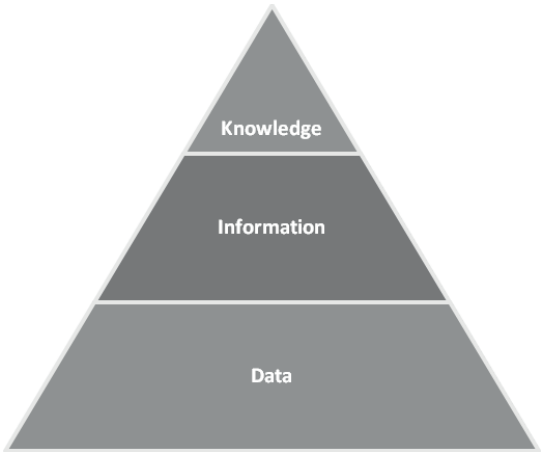


Figure D-1: The tradition approach for portraying the relationship between data- information-knowledge

Knowledge as a term is described in literature as "*a multifaceted concept with multilayered meanings*", and can be defined as "*justified true belief*" (Nonaka 1994). Given that information is regarded as a flow of messages, then knowledge is created and organized by this flow of messages; i.e. information is the necessary material for creating knowledge. The knowledge that is created is further anchored in the beliefs and commitments of the knowledge holder. This relates the construct of knowledge to human actions, as fits the subjective nature of knowledge (Nonaka 1994). This notion is supported by Malhotra who also stresses the importance of the human and personal aspects in the translation of information into knowledge, actions, and performance (Malhotra 2001). This implies that

knowledge is something more than just the product of all information elements, or a "commodity" that is extracted from data and information cfr. Figure D-1. A more pragmatic approach to knowledge has been proposed by Court (Court 1995) who describes knowledge as the ability of the individual to understand information, including how they handle, apply, and use it in a given situation. Common for these approaches is that generation of knowledge is described as within-person capacity. The present research project does not deal with different ways of creating knowledge, as learning, unlearning, tacit, or explicit knowledge as thoroughly described by Ringen (Ringen 2010). Rather, the aim of this research has been to identify, collected, and compile sustainability information with the potential of creating knowledge in product development and design.

D.2 Information quality

Information quality is of critical importance as the sustainability information defined and identified in this research project may be used to create knowledge which may further be used in decision making processes in product development and design. Basing decisions on incorrect information in product development and design may have substantial negative consequences. The final product may be designed with wrong or lacking environmental and social attributes, thus needing a costly redesign before market entry, or the product may fail in the market due to missing sustainability properties.

Information is seldom ideal or free of error. In order to define the right quality of sustainability information, a basic understanding of the constructs of quality is necessary. According to the ISO 9000:2005, quality can be defined as the "*degree to which a set of inherent characteristics fulfills requirements*", whereas requirements is further defined as "*need or expectation*" (ISO 2005). This definition is basically developed for firms aiming at complying with a certain ISO standard, and is perhaps not easy to translate and use when it comes to defining quality requirements for sustainability information. Another frequently used definition of quality is Juran's definition: "*fitness for use*", in which fitness is defined by the customer (ASQ 2011). There are many more definitions of quality, but since no common definition has been universally agreed upon, these two will be used as the point of departure in the following.

An important first step is to decide who within a firm is the customer of information. As the present research project is about sustainability information relevant to sustainable product development, product developers, product designers, engineers, and others working in an interdisciplinary team with product development, both operationally and strategically, are denoted as information customer. The above described definitions further presuppose a

fulfillment of requirements or fitness for use. This implies that a set of requirements regarding the information at hand must be fulfilled.

Various research fields have been searched to find what other researchers define as requirements for information quality. Quality aspects of information have been studied by researchers mainly in fields like management information systems, computing, databases and their management, and data warehouse quality (Lee et al. 2002, Uotila and Melkas 2007).

Salaün and Flores examine information in a consumer context and define good quality information as "*information which satisfies criteria of appreciation specified by the user, together with a certain standard requirement"* (Salaün and Flores 2001). The reported information quality criteria in their article include "*continuous exchange"* to promote learning, *"reliability of exchanges", "relevance", "personalization of exchanges", "accessibility",* and *"understanding the information content"*.

Lee et al. have a different approach, i.e. developing a methodology for information quality assessment and benchmarking (Lee et al. 2002). According to Lee et al., organizations that lack the ability to assess the quality of their information, cannot assess the status of their organizational information quality and hence monitor improvements. They group information quality into four dimensions: "*intrinsic"*, "*contextual"*, "*representational"*, and "*accessibility"*, and hence provide a methodology for information quality assessment based on literature within management information systems.

Information quality in interorganizational systems use is yet another approach by Hartono et al. (Hartono et al. 2010). Based on scientific literature, they identified information "*usefulness", "accuracy",* and *"accessibility"* as main information quality requirements.

Uotila and Melkas look into information quality from a foresight process perspective and emphasize "*relevancy"*, "*timeliness"*, "*completeness"*, "*objectivity"* and "*applicability"* (Uotila and Melkas 2007).

Information and knowledge capturing, storing, and reusing in respect to engineering design are key issues for Hicks et al. Based on Turner, they define truly "*useful"* information as "*available", "authentic", "applicable"*, and *"accessible"* (Hicks et al. 2002).

Forza and Salvador have, based in the field of organization science, identified the following criteria for classifying information: "*purpose/function"*, "*degree of formalization"*, "*direction"*, and "*media richness"* (Forza and Salvador 2001).

Table D-1 includes a subset of information quality requirements identified in literature. Common for this identified literature, is the fact that there seems to be no common classification system for information quality requirements that all researchers agree upon. Hence, an important conclusion that can be drawn from the reviewed literature is that information quality requirements are context and purpose dependent, that is, the requirements depend on the problem at hand and the context in which the information will be used.

Table D-1: Information quality requirements identified in literature

Quality Requirements	Explanation
Continuous exchange (Salaün and Flores 2001)	Concerns a continuous and repeated exchange of information to promote learning based on past experiences and memorization.
Reliability (Salaün and Flores 2001)	Concerns the reliability and trustworthiness.
Accessibility (Salaün and Flores 2001, Hicks et al. 2002, Lee et al. 2002, Hartono et al. 2010)	Concerns through which means information is transmitted and the search price for the information. Information must be accessible and easy to obtain. Examples of keywords identified are reliability, obtainability, flexibility, and convenience of access.
Availability (Hicks et al. 2002)	Concerns information being present and ready for use, or at hand (Dictionary 1991).
Personalization (Salaün and Flores 2001)	Concerns how a continuous exchange process of information may lead to more interpersonal relationships.
Usefulness (Hartono et al. 2010)	Concerns the information being practical and possible to use.
Relevance (Salaün and Flores 2001, Uotila and Melkas 2007)	Concerns how information needs can be met accurately and quickly.
Contextuality (Forza and Salvador 2001, Lee et al. 2002)	Concerns that information quality must be based on the context of the task, it must be relevant, timely, and complete and add value. Examples of keywords identified are timeliness, completeness, relevance, appropriate amount, source, usefulness, sufficiency, and informativeness.
Representationality (Lee et al. 2002)	Concerns that information must be presented in an interpretable way, be easy to understand, concise, and consistent. Examples of keywords identified are uniqueness, consistency, and precision of domains, understandability, reasonable, meaningfulness, appropriate representation, interpretability, and identifiability.
Applicability (Hicks et al. 2002, Uotila and Melkas 2007)	Concerns applicability in firms and in other organizations. It also concern accessibility, value added, interpretability, ease of understanding, ease of operation, and believability. Concerns information that can be applied, that is relevant or appropriate (Dictionary 1991).
Completeness (Uotila and Melkas 2007)	Concerns information being complete enough to make sense for the product developer and to portray correctly what it describes (Dictionary 1991).
Timeliness (Uotila and Melkas 2007)	Concerns information occurring at a suitable time, have good timing (Dictionary 1991).

Quality Requirements	Explanation
Objectivity (Uotila and Melkas 2007)	Concerns information being neutral or value-neutral (Dictionary 1991).
Accuracy (Hartono et al. 2010)	Concerns information representing a fact with precision and exactness.
Understandability (Salaün and Flores 2001)	Concerns how information is presented to the recipient in an understandable manner.
Intrinsic (Lee et al. 2002)	Concerns information having qualities in its own right. Examples of keywords identified are accuracy, completeness, validity, consistency, correctness, believability, reputation, objectivity, factuality, precision, reliability, and unambiguity.
Authenticity (Hicks et al. 2002)	Concerns information conforming to fact and therefore worthy of trust, reliance, or belief. Or having a claim of verified origin or authorship (Dictionary 1991).

Taking the practitioners' pragmatic view on sustainability information quality, it is possible to propose three overarching requirements that must be fulfilled when it comes to information quality;

1. *Importance*: Sustainability information must be considered important to product development by product developers. Information may be considered relevant or useful to product development, but still not be important. On the other hand, information important to product developers can not be important unless it is also relevant or useful. Issues within this dimension are proposed to be: timeliness, completeness, relevance, appropriate amount, source, usefulness, sufficiency, and informativeness.
2. *Accuracy*: Information must be accurate, meaning the information must represent a fact with some degree of precision and exactness. Accuracy deals with issues like completeness, validity, consistency, correctness, believability, reputation, objectivity, factuality, reliability, and unambiguity.
3. *Accessibility*: Information must be accessible and easily obtainable. Accessibility has to do with dimensions as exchange of information, information flow, obtainability, convenience of access, etc. If the search cost for information is considered too high by the product developer, the information will not be identified and consequently not used in product development.

To summarize, the user of sustainability information or the information customer, is anyone in the organization involved in product development and design. The context in which the information will be used is the product development process within a firm. Figure D-2 summarizes the proposed way of dealing with quality requirements regarding sustainability information relevant to product development and design in the present research project.

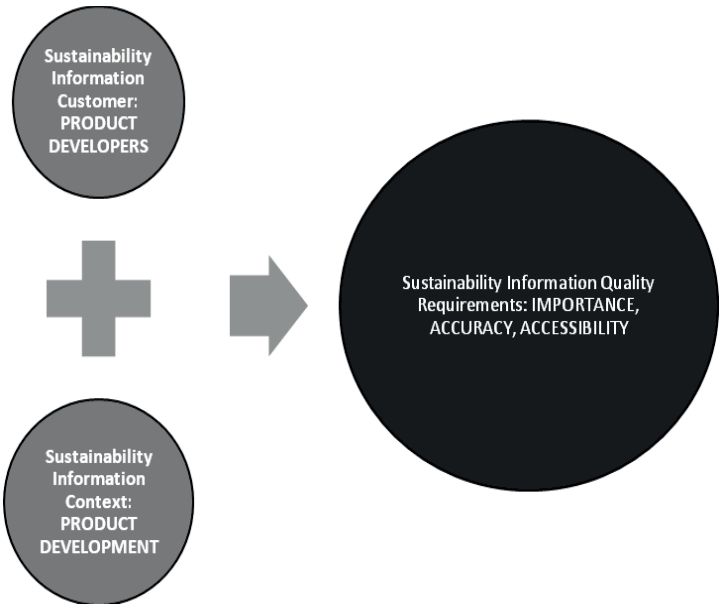


Figure D-2: Quality aspects of sustainability information

Appendix E: Stakeholder theory

The roots of the stakeholder approach to strategic management go back to the first publication of Freeman's seminal book Strategic Management: A Stakeholder Approach in 1984 (Freeman 1984). In this book, stakeholders were for the first time defined as something more than owners or stockholders (Clement 2005). Freeman defined stakeholders more broadly than before as "*any group or individual who can affect or is affected by the achievement of the firms' objectives*" (Freeman 1984). Freeman's stakeholder theory immediately gained much popularity among both researchers and practitioners who pursued examining and refining the stakeholder concept from different perspectives (Donaldson and Preston 1995, Clement 2005). Today stakeholder theory has a wide range of applications, from project management (Aaltonen et al. 2008), green marketing (Polonsky and Ottman 1998), environmental knowledge production (Hage et al. 2010), corporate environmental information collection, management, and communication (Erlandsson and Tillman 2009), to describing and explaining specific firm characteristics and behaviors (Donaldson and Preston 1995), and the more traditional business management perspectives (Ackermann and Eden , Andersen and Fagerhaug 2002, Clement 2005).

E.1 What are stakeholders?

Central in stakeholder theory is the definition of who the stakeholders are and which stakeholder groups a firm should pay attention to. Freeman's stakeholder definition has later been loosely referred to as *"anything influencing or influenced by the firm"*. This definition opens up an excessive and great scope in stakeholder identification compared to earlier management literature (Donaldson and Preston 1995). The fundamental newness of the stakeholder theory was to include for instance dissimilar groups like community organizations, environmentalists, special interest groups, and media as legitimate stakeholders, and to go beyond the traditional input-output model of investors, suppliers, employees and customers (Donaldson and Preston 1995, Clement 2005). Donaldson and Preston, later described stakeholders in one of their central theses as "….*persons or groups with legitimate interests in procedural and/or substantive aspects of corporate activity. Stakeholders are indentified by their interest in the corporation, whether the corporation has any corresponding functional interest in them*". They further present that "….*the interests of all stakeholders are of intrinsic value. That is, each group of stakeholders merits consideration for its own sake and not merely because of its ability of furthering the interest of some other groups, such as the shareowners*" (Donaldson and Preston 1995).

The latter indicates that stakeholders should be treated for their own merit, and not as a means to achieve other goals.

Stakeholders have also been defined as those "*organizations, institutions or persons affected by or with a vested interest in the organization and its business processes. They hold expectations with regard to products and services delivered by the organization through business processes that produce these products or services, and support and enable the production of them*" (Andersen 1999).

No matter which stakeholder definition is used, the overarching assumption is that a firm has relations to many groups and organizations. These groups are affected by the firm itself, but also affect the firm themselves. Furthermore, who the stakeholders are will be related to the different stakes they have in or demands they can make on a firm (Ackermann and Eden) .

E.2 Which stakeholder groups should be considered?

Literature does not give a clear answer to which stakeholder groups should be considered by a firm as this may be situation specific and depend on the problem at hand. However, frequently listed stakeholder groups are: employees, investors, suppliers, legislators, governmental agencies, environmentalists, retailers, the media, children, management, shareholders, scientific communities, unions, competitors, the courts, special interest groups, local, state, and federal governments, and the general public (Polonsky 1995). For the purpose of this dissertation and the following discussion, we have limited our stakeholder groups to 11 different main groups: management, employees, shareholders, financial institutions, competitors, customers, non-governmental organizations (NGOs), trade organizations, media, government, academia (scientific community), and suppliers. However, the use of stakeholder groups varies in the research project dependent on the situation at hand, i.e. the research question to be explored. Figure E-1 demonstrates a typical example of how a firm and its stakeholder groups are frequently portrayed in literature. The arrows between the firm and its stakeholders run two ways to demonstrate the mutual exchange process of money, goods, information, and expectations (Andersen and Fagerhaug 2002). In this research project, the information (including expectation) flow is of particular interest.

The designation *customers* includes end-customers, i.e. users of a product, but also value chain customers. Information wise, they all have important information to contribute. *Non-governmental organizations (NGOs)* are legally constituted organizations which operate independently of the government. They can typically be environmental organizations

aiming to influence the public. *Media* include all relevant media channels, that is, the traditional channels like TV, radio, newspapers, magazines, but also information on internet through new channels like Twitter, LinkedIn, Facebook, YouTube, Wikipedia, etc. The *government* includes the central government in a country, but also the local government in the community. The term *financial institutions* are used designating banks and lending institutions that provide a firm with capital and loans. It also includes insurance companies that insure the firms in different ways based on risk assessments.

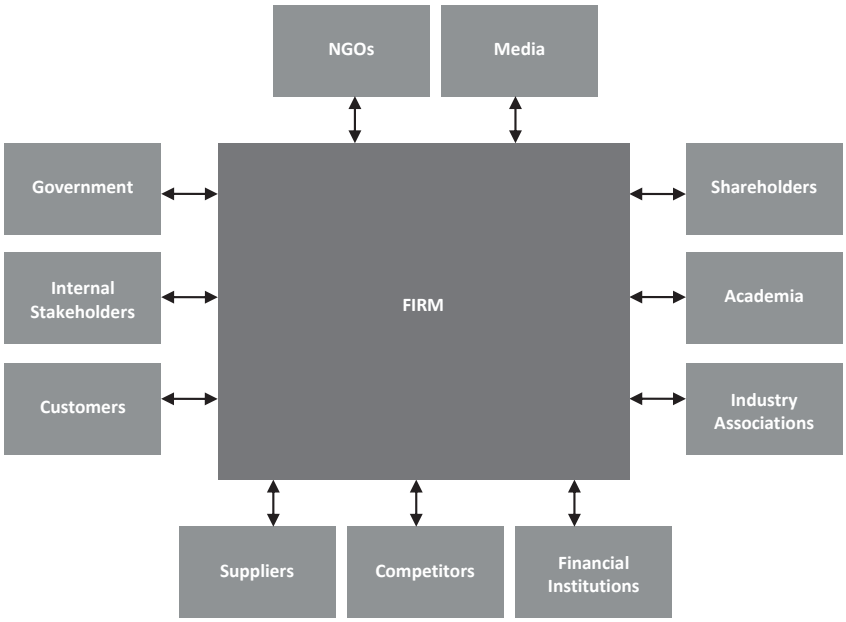


Figure E-1: Stakeholder interaction with firm

Suppliers are all company that provides the firm with material input, in the form of parts, materials, and semi-products. *Academia* are research institutions, both public like universities, but also private institutions that function as knowledge brokers. The term s*hareholders* is used for anyone having shares in the firm, or having invested capital in the firm. A shareholder may be either a group of investors or a single person. *Employees* are those working in a firm, including management and unions. *Industry associations* will be any group that works to promote the conditions of a particular industry, an interest group,

or organization. Finally, *competitors* are all firms or individual producing a similar product within the same market.

Stakeholder management is a complicated matter for most firms, as the objectives of the various stakeholder groups are often different, and to some extent contradictive. Shareholders may for instance be in the market for profit maximization, whereas employees may expect safe working conditions. Therefore, following one strategy will not allow for all expectations to be met.

Stakeholders may not only affect the firm directly, stakeholders may also interact with each other (Polonsky 1995). Consumers may for instance boycott financial institutions that lend money to firms with poor environmental records, and this may cause a chain of events where stakeholder groups cause other stakeholder groups to pressure a firm to change its environmental practices (Polonsky 1995, Lundgren and Catasus 2000). In an information perspective, it is consequently important to consider the effect stakeholders may have on each other.

E.3 Why may stakeholders be good sources of sustainability information?

The main reason for using the stakeholders approach in this research project is that all firms have stakeholders. Who the stakeholders are may vary from firm to firm, and from situation to situation. For practical reasons, typical stakeholders are denoted as stakeholder groups in this research. The most typical stakeholder groups for a manufacturing firm with in-house product development are hence identified in Figure E-1.

Another important reason why the stakeholder approach in collecting information is expected to be fruitful, is the ongoing exchange process of money, goods, information, and expectations between stakeholders and a firm, (Andersen and Fagerhaug 2002). By identifying information and expectations flowing between firm stakeholders on sustainability issues, new and previously unexploited information relevant to sustainable product development and design may be discovered. Except for Erlandsson and Tillman (2009) and Foster and Green (2000) this approach has not been much explored in research (Foster and Green 2000, Erlandsson and Tillman 2009). Consequently, this should be an interesting approach in searching for sustainability information.

A third reason is concerned with communication issues. The term stakeholder is nowadays commonly adopted and understood by most firms, hence communicating about and with stakeholders is expected to be easy. This is an important issue when it comes to the

practicalities of the research project, i.e. that the interviewees easily can understand the problem at hand.

Finally, the use of stakeholders allows for systematic collection of information related to sustainable product development and design concerned with *"anything influencing or influenced by the firm"* (Donaldson and Preston 1995). This is a much wider approach than traditionally adopted through sustainable supply chain management (Seuring and Müller 2008, Seuring et al. 2008), which is only concerned with firms and organizations either upstream of downstream or downstream the focal firm. A traditional approach will most likely include all "primary stakeholders", but not necessarily. Insurance firms or investors may not be considered in the supply chain perspective. Moreover, important stakeholders' information sources like the government, NGOs, media, and industry associations are omitted in the traditional supply chain view. Consequently, the wider stakeholder approach for identifying sustainability information seems viable in the present context.

E.4 Stakeholder taxonomies

It is common to classify stakeholders according to taxonomies like internal (inside the firm) or external stakeholders (outside the firm), and as primary or secondary stakeholders. Primary stakeholders are those who have a formal, official, or contractual relationship with a firm. They also have direct influence upon the organization. Secondary stakeholder groups are not directly engaged in the firm's economic activities, but can nevertheless exert influence or affect the organization (Polonsky 1995). Other stakeholder taxonomies have also been developed, based on degrees of environmental pro-activity in environmental management (Henriques and Sadorsky 1999), based on degrees of corporate social performance (Clarkson 1995), based on the linkage between proactive environmental strategy and stakeholder management (Buysse and Verbeke 2003, González-Benito and González-Benito 2006, González-Benito and González-Benito 2008), or power, criticality, and rationality (Jonker and Foster 2002). Common for these taxonomies are that they are all based on a classification system related to a particular issue - either economic, environmental, or corporate social.

In this research project, the aim is to identify sustainability information relevant to product development and design. As the term sustainability comprises all the above issues at once (environmental, social, and economical), none of the reviewed classification systems or stakeholder taxonomies are considered suitable. Based on an extensive literature search, a comprehensive stakeholder taxonomy based on sustainability issues does not yet seem to

have been developed, possibly because it is considered to be too complex. Moreover, all existing taxonomies adopt an underlying management perspective. The present research project is looking for information relevant to product development and design, which is not considered a managerial process. Issues affecting managerial decisions on strategic levels may not be the same as those relevant on product development and design level.

To conclude, in the present research project, in which the aim is to identify sustainability information relevant to product development and design, traditional stakeholder taxonomies are considered of little value, except for the overall classification of internal vs. external stakeholders.

Appendix F: Sustainable product development tools and methods

Sustainable product development and design have evolved over the years from a narrow environmental focus, to focusing on a process that considers the environmental, social, and economical aspects of a product over its entire lifetime (Bhamra and Lofthouse 2007). Table F-1 below summarizes main evolutionary steps.

Table F-1: The evolution of sustainability considerations in design (Bhamra and Lofthouse 2007)

Green Design	Green design focus on singles issues, for example the inclusion of recycled or recyclable plastic, or considerations of energy consumption.
Ecodesign	Environmental impacts are considered at each of at the design process throughout the product life cycle.
Design for Sustainability	Design that considers the environmental (for example resource use, end of life impact) and social impact of products (for example usability, responsible use, designing to address human needs, social procurement).
Sustainability	Sustainability is considered to be more a direction than a destination that is actually reached.

Researchers and practitioners have developed a myriad of different tools and methods to help the designer to make environmental and sustainability considerations covering the product's life cycle (Baumann et al. 2002). Some examples of such tools are (not a complete list):

- Design for sustainability – a step by step approach is an update to the previous manual called Ecodesign: A promising Approach to Sustainable Production and Consumption from 1997. The manual features three approaches for meeting the environmental, social, and economical aspects of products through 1) redesign, 2) new product development, and 3) product service systems (United Nations Environment Programme 2009).
- Ten Golden Rules includes generic advice for merging environmental aspects into in the goal and specification phase of product development. The tool was developed to facilitate the integration of reasonable environmental demands into the product development process (Luttropp and Lagerstedt 2006).
- 10 guidelines for ecodesign is a web-based tool for almost every possible need in ecodesign and related issues (http://www.pre.nl/ecodesign/ecodesign.htm).
- Ecodesign Web provides a quick way of helping the product developer identify which key areas of the product one should be focusing upon to improve the product's environmental performance (Lofthouse 2006, Bhamra and Lofthouse 2007).
- Environmental improvement through product development is a stepwise approach to actively integrating environmental consideration into companies' design and product

development activities, in order to create synergies between environment and business creation. The method is based on a life cycle view of the products and includes seven solution-oriented steps towards environmental improvement (McAloone and Bey 2009).

- Ecodesign implementation consists of a twelve-step procedure for integrating significant environmental aspects of a product and environmental stakeholder requirements into product development. The method is mainly developed for redesign of existing products and aims at improving both the overall performance of a product, and specifically the environmental performance (Wimmer et al. 2004).
- LCA according to ISO 14001 is a framework for assessing the environmental impact of a product, process, or service throughout its lifecycle and is today widely used by product developers (Goedkoop and Spriensma 2001, Hauschild et al. 2005, Bhamra and Lofthouse 2007).
- MET matrix (materials, energy, toxic emissions) is an abridged LCA tool which can be used in first design phases (Bhamra and Lofthouse 2007). It is a fairly simple tool that helps product developers understand the environmental problems associated with the product they are working on.
- Eco-indicator 99 is a structured impact assessment methodology intended to be used as a tool for product developers and designers, which is also an abridged LCA tool. The Eco-indicator methodology can be used to calculate the environmental impacts of a product design in two different ways (Goedkoop and Spriensma 2001).

Many of these tools only to a limited extent cater to sustainability information from stakeholders. They typically focus on other aspects as issues relating to the manufacturing process of the product, or they focus on information regarding the product itself. Product and process data and information are predominantly the input into all these tools and methods. More intangible factors like information on up-coming regulations from the European Commission, or information on supplier work practices, or information on competitors' marketing material have only to little extent been systematically reviewed and made part of tools for sustainable product development. Hence, sustainability information may provide a valuable addition to the current product – process data approach in product development and design today.

References

Aaltonen, K., K. Jaakko, and O. Tuomas. 2008. Stakeholder salience in global projects. International Journal of Project Management **26**:509-516.

Ackermann, F. and C. Eden. Strategic Management of Stakeholders: Theory and Practice. Long Range Planning **In Press, Corrected Proof**.

Albino, V., A. Balice, and R. Maria. 2009. Environmental strategies and green product development: an overview on sustainability-driven companies. Business Strategy and the Environment **18**:83.

Alniacik, U., E. Alniacik, and N. Genc. 2010. How corporate social responsibility information influences stakeholders' intentions. Corporate Social Responsibility and Environmental Management:n/a-n/a.

Altham, W. 2007. Benchmarking to trigger cleaner production in small businesses: drycleaning case study. Journal of Cleaner Production **15**:798-813.

Andersen, B. 1999. Business process imporovement toolbox. ASQ Press, Milwaukee.

Andersen, B. 2007. Business Process Improvement Toolbox. Second edition. American Society for Quality, ASQ Qualtiy Press, Milwaukee.

Andersen, B. and T. Fagerhaug. 2002. Performance Measurement Explained. Designing and Implementing Your State-of-the-Art System. ASQ Press, Milwaukee.

Andersen, B., T. Fagerhaug, B. Henriksen, and L. E. Onsøyen. 2008. Mapping work processes. American Society for Quality, ASQ Qualtiy Press, Milwaukee.

Andreasen, M. M. and L. Hein. 1986. Integrert produktutvikling (eng. integral product development). Universitetsforlaget AS.

Angerer, G., R. Nordbeck, and C. Sartorius. 2008. Impacts on industry of Europe's emerging chemicals policy REACh. Journal of Environmental Management **86**:636-647.

Arbnor, I. and B. Bjerke. 2009. Methodology for creating business knowledge. Third Edition edition. Sage.

Aschehoug, S. and C. Boks. 2010. Sustainability Information in Product Development - the Case of Automotive Supplier Industry. APMS 2010, Internation Conferance on Advances in Production Management Systems, Cernobbio, Italy.

Aschehoug, S. and C. Boks. 2011. Success criteria for implementing sustainability information in product development.*in* ICED 11, 18th International Conference on Engineering Design. the Design Society, Copenhagen, Denmark.

Aschehoug, S. and C. Boks. 2012a. Building sustainability knowledge for product development and design - Experiences from four manufacturing firms. Submitted to Progress in Industrial Ecology, An International Journal.

Aschehoug, S., C. Boks, and S. Storen. 2009. A framework for identification of environmental information among stakeholders. EcoDesign 2009 - 6th International Symposium on Environmental Conscious Design and Inverse Manufacturing, Sapporo, Japan.

Aschehoug, S. H. and C. Boks. 2012b. Towards a framework for sustainability information in product development. International Journal of Sustainable Engineering:1-15.

Aschehoug, S. H., C. Boks, and S. Støren. 2012. Environmental information from stakeholders supporting product development. Journal of Cleaner Production **31**:1-13.

Aslaksen, I. and T. Synnestvedt. 2003. Ethical investment and the incentives for corporate environmental protection and social responsibility. Corporate Social Responsibility and Environmental Management **10**:212-223.

ASQ. 2011. Glossary - Entry Quality. American Society for Quality.

Bai, C. and J. Sarkis. 2010. Green supplier development: analytical evaluation using rough set theory. Journal of Cleaner Production **18**:1200-1210.

Bartolomeo, M., D. dal Maso, P. de Jong, P. Eder, P. Groenewegen, P. Hopkinson, P. James, L. Nijhuis, M. Örninge, G. Scholl, A. Slob, and O. Zaring. 2003. Eco-efficient producer services--what are they, how do they benefit customers and the environment and how likely are they to develop and be extensively utilised? Journal of Cleaner Production **11**:829-837.

Baumann, H., F. Boons, and A. Bragd. 2002. Mapping the green product development field: engineering, policy and business perspectives. Journal of Cleaner Production **10**:409-425.

Berchicci, L. and W. Bodewes. 2005. Bridging environmental issues with new product development. Business Strategy and the Environment **14**:272.

Bhamra, T. and V. Lofthouse. 2007. Design for Sustainability - A Practical Apporach. Gower.

Blomgren, A. 2010. Does corporate social responsibility influence profit margins? a case study of executive perceptions. Corporate Social Responsibility and Environmental Management:n/a-n/a.

Blomquist, T. and J. Sandström. 2004. From issues to checkpoints and back: managing green issues in R&D. Business Strategy and the Environment **13**:363-373.

Boks, C. 2006. The soft side of ecodesign. Journal of Cleaner Production **14**:1346-1356.

Boks, C. and A. Stevels. 2003. Theory and practice of environmental benchmarking in a major consumer electronics company. Benchmarking - An International Journal **10**:120-135.

Boons, F. 2002. Greening products: a framework for product chain management. Journal of Cleaner Production **10**:495-505.

Bos-Brouwers, H. E. J. 2009. Corporate sustainability and innovation in SMEs: evidence of themes and activities in practice. Business Strategy and the Environment.

Boyd, G., E. Dutrow, and W. Tunnessen. 2008. The evolution of the ENERGY STAR® energy performance indicator for benchmarking industrial plant manufacturing energy use. Journal of Cleaner Production **16**:709-715.

Braganza, A. 2004. Rethinking the data-information-knowledge hierarchy: towards a case-based model. International Journal of Information Management **24**:347-346.

Brown, H. S., M. de Jong, and D. L. Levy. 2009. Building institutions based on information disclosure: lessons from GRI's sustainability reporting. Journal of Cleaner Production **17**:571-580.

Buysse, K. and A. Verbeke. 2003. Proactive Environmental Strategies: A Stakeholder Management Perspective. Strategic Management Journal **24**:453-470.

Callan, S. J. and J. M. Thomas. 2009. Corporate financial performance and corporate social performance: an update and reinvestigation. Corporate Social Responsibility and Environmental Management **16**:61-78.

Carlson, R., M. Erixon, P. Forsberg, and A. C. Pålsson. 2001. System for integrated business environmental information management. Advances in Environmental Research **5**:369-375.

Carlson, R. and A.-C. Pålsson. 2001. Industrial environmental information management for technical systems. Journal of Cleaner Production **9**:429-435.

Casper Boks, A. S. 2003. Theory and practice of environmental benchmarking in a major consumer electronics company. Benchmarking - An International Journal **10**:120-135.

Castka, P., M. A. Balzarova, C. J. Bamber, and J. M. Sharp. 2004. How can SMEs effectively implement the CSR agenda? A UK case study perspective. Corporate Social Responsibility and Environmental Management **11**:140-149.

Chamorro, A., S. Rubio, and F. Miranda. 2009. Characteristics of research on green marketing. Business Strategy and the Environment **18**:223.

Charter, M. and U. Tischner. 2001. Sustainable solutions: developing products and services for the future. Greenleaf Publishing Ltd., Sheffield, United Kingdom.

Clarkson, M. B. E. 1995. A Stakeholder Framework for Analyzing and Evaluating Corporate Social Performance. The Academy of Management Review **20**:92-117.

Clement, R. W. 2005. The lessons from stakeholder theory for U.S. business leaders. Business Horizons **48**:255-264.

Clift, R., R. Malcolm, H. Baumann, L. Connell, and G. Rice. 2005. Eco-labels and Electric Monks. Journal of Industrial Ecology **9**:4-7.

Cooper, T. 2005. Slower Consumption Reflections on Product Life Spans and the "Throwaway Society". Journal of Industrial Ecology **9**:51-67.

Court, A. W. 1995. Modelling and classification of information for engineering and design, PHD thesis. University of Bath, UK.

Cramer, J. 2002. From financial to sustainable profit. Corporate Social Responsibility and Environmental Management **9**:99-106.

Cross, N. 2008. Engineering Design Methods - Strategies for Product Design. Fourth edition. John Wiley & Sons Ltd, England.

Darnall, N., N. Jason, and R. Handfield. 2008. Environmental management systems and green supply chain management: complements for sustainability? Business Strategy and the Environment **17**:30.

Daub, C.-H. 2007. Assessing the quality of sustainability reporting: an alternative methodological approach. Journal of Cleaner Production **15**:75-85.

de Boer, J. 2003. Sustainability labelling schemes: the logic of their claims and their functions for stakeholders. Business Strategy and the Environment **12**:254-264.

Del Río, P., J. Carrillo-Hermosilla, and T. Könnölä. 2010. Policy Strategies to Promote Eco-Innovation. Journal of Industrial Ecology **14**:541-557.

Delmas, M. and M. W. Toffel. 2004. Stakeholders and environmental management practices: an institutional framework. Business Strategy and the Environment **13**:209-222.

Dictionary. 1991. Random House Webster's College Dictionary.*in* R. B. Costello, editor. Random House, New York.

Dobers, P. and R. Wolff. 2000. Competing with 'soft' issues – from managing the environment to sustainable business strategies. Business Strategy and the Environment **9**:143-150.

Donaldson, T. and L. E. Preston. 1995. The Stakeholder Theory of the Corporation: Concepts, Evidence, and Implications. The Academy of Management Review **20**:65-91.

Duarte, A. P., P. Martins, and J. Alexandre. 2008. Pro-active behaviour induction by integration of sustainability in business strategic management: INOVE project case study. Journal of Cleaner Production **16**:1127-1132.

Ehrenfeld, J. R. 2008. Sustainability by Design: A Subversive Strategy for Transforming Our Consumer Culture. Yale University Press.

Ekvall, T., A.-M. Tillman, and S. Molander. 2005. Normative ethics and methodology for life cycle assessment. Journal of Cleaner Production **13**:1225-1234.

Elkington, J. 1998. Cannibals with Forks - The Triple Bottom Line of 21st Century Business. Capstone Publishing Ltd., Oxford, United Kingdom.

Epstein, M. J. 2008. Making sustainability work - Best Practices in Managing and Measuring Corporate Social, Evironmental and Economic Impacts. Greenleaf Publishing.

Erlandsson, J. and A.-M. Tillman. 2009. Analysing influencing factors of corporate environmental information collection, management and communication. Journal of Cleaner Production **17**:800-810.

Faruk, A. C., R. C. Lamming, P. D. Cousins, and F. E. Bowen. 2001. Analyzing, Mapping, and Managing Environmental Impacts along Supply Chains. Journal of Industrial Ecology **5**:13-36.

Ferrão, P., P. Nazareth, and J. Amaral. 2006. Strategies for Meeting EU End-of-Life Vehicle Reuse/Recovery Targets. Journal of Industrial Ecology **10**:77-93.

Figge, F. and T. Hahn. 2005. The Cost of Sustainability Capital and the Creation of Sustainable Value by Companies. Journal of Industrial Ecology **9**:47-58.

Finch, B. J. 1999. Internet discussions as a source for consumer product customer involvement and quality information: an exploratory study. Journal of Operations Management **17**:535-556.

Finster, M., P. Eagan, and D. Hussey. 2001. Linking Industrial Ecology with Business Strategy: Creating Value for Green Product Design. Journal of Industrial Ecology **5**:107-125.

Forslind, K. H. 2009. Does the financing of extended producer responsibility influence economic growth? Journal of Cleaner Production **17**:297-302.

Forza, C. and F. Salvador. 2001. Information flows for high-performance manufacturing. International Journal of Production Economics **70**:21-36.

Foster, C. and K. Green. 2000. Greening the innovation process. Business Strategy and the Environment **9**:287.

Freeman, R. E. 1984. Strategic Management: A stakeholder approach. Pitman Publishing Company, Boston.

Frieder, J. B. 2002. Using Information: A Financial Stakeholders' Perspective. Corporate Environmental Strategy **9**:375-378.

Frysinger, S. P. 2001. An integrated environmental information system (IEIS) for corporate environmental management. Advances in Environmental Research **5**:361-367.

Führ, M. and K. Bizer. 2007. REACh as a paradigm shift in chemical policy - responsive regulation and behavioural models. Journal of Cleaner Production **15**:327-334.

Gallego, I. 2006. The use of economic, social and environmental indicators as a measure of sustainable development in Spain. Corporate Social Responsibility and Environmental Management **13**:78-97.

Gehin, A., P. Zwolinski, and D. Brissaud. 2008. A tool to implement sustainable end-of-life strategies in the product development phase. Journal of Cleaner Production **16**:566-576.

Geldermann, J. and O. Rentz. 2004. The reference installation approach for the techno-economic assessment of emission abatement options and the determination of BAT according to the IPPC-directive. Journal of Cleaner Production **12**:389-402.

Gericke, K. and L. Blessing. 2011. Comparison of design methodologies and process models across disciplines: a literature review. International Conference on Engineering Design, ICED11, Copenhage.

Gerrard, J. and M. Kandlikar. 2007. Is European end-of-life vehicle legislation living up to expectations? Assessing the impact of the ELV Directive on [`]green' innovation and vehicle recovery. Journal of Cleaner Production **15**:17-27.

Gilg, A., S. Barr, and N. Ford. 2005. Green consumption or sustainable lifestyles? Identifying the sustainable consumer. Futures **37**:481-504.

Goedkoop, M. and R. Spriensma. 2001. The Eco-Indicator 99 A damage oriented method for Life Cycle Impact Assessment. The Dutch Ministry of Housing, Spatial Planning and the Environment (VROM).

Gold, S., S. Seuring, and P. Beske. 2010. Sustainable supply chain management and inter-organizational resources: a literature review. Corporate Social Responsibility and Environmental Management **17**:230-245.

González-Benito, J. and Ó. González-Benito. 2006. A review of determinant factors of environmental proactivity. Business Strategy and the Environment **15**:87-102.

González-Benito, J. and Ó. González-Benito. 2008. A study of determinant factors of stakeholder environmental pressure perceived by industrial companies. Business Strategy and the Environment.

Griese, H. 2007. Global Sustainable Development Need Advanced Electronics. Proceedings of EcoDesign 2007, Tokyo, Japan.

Haddock-Fraser, J. E. and M. Tourelle. 2010. Corporate motivations for environmental sustainable development: exploring the role of consumers in stakeholder engagement. Business Strategy and the Environment **19**:527-542.

Hage, M., P. Leroy, and A. C. Petersen. 2010. Stakeholder participation in environmental knowledge production. Futures **42**:254-264.

Haigh, M. and J. Guthrie. 2010. Management practices in Australasian ethical investment products: a role for regulation? Business Strategy and the Environment **19**:147-163.

Hallstedt, S., H. Ny, K.-H. Robèrt, and G. Broman. 2010. An approach to assessing sustainability integration in strategic decision systems for product development. Journal of Cleaner Production **18**:703-712.

Halme, M. and J. Niskanen. 2001. Does corporate environmental protection increase or decrease shareholder value? The case of environmental investments. Business Strategy and the Environment **10**:200.

Handfield, R., R. Sroufe, and S. Walton. 2005. Integrating environmental management and supply chain strategies. Business Strategy and the Environment **14**:1.

Hartono, E., X. Li, K.-S. Na, and J. T. Simpson. 2010. The role of the quality of shared information in interorganizational systems use. International Journal of Information Management **30**:399-407.

Hauschild, M., J. Jeswiet, and L. Alting. 2005. From Life Cycle Assessment to Sustainable Production: Status and Perspectives. CIRP Annals - Manufacturing Technology **54**:1-21.

Henriques, I. and P. Sadorsky. 1999. The Relationship between Environmental Commitment and Managerial Perceptions of Stakeholder Importance. The Academy of Management Journal **42**:87-99.

Hicks, B. J., S. J. Culley, R. D. Allen, and G. Mullineux. 2002. A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design. International Journal of Information Management **22**:263-280.

Hirschl, B., W. Konrad, and G. Scholl. 2003. New concepts in product use for sustainable consumption. Journal of Cleaner Production **11**:873-881.

Hoffmann, E. 2007. Consumer integration in sustainable product development. Business Strategy and the Environment **16**:322.

Honkasalo, A. 2001. Eco-efficiency and Integrated Product Policy: Lessons from Finland. Corporate Environmental Strategy **8**:109-117.

Howarth, G. and M. Hadfield. 2006. A sustainable product design model. Materials & Design **27**:1128-1133.

http://www.pre.nl/ecodesign/ecodesign.htm. 10 Guidelines for Ecodesign.*in* P. E. Consultants, editor.

Hubka, V., M. M. Andersen, and W. E. Eder. 1988. Practical studies in systematic design. Butterworth&Co UK.

Hutchins, M. J. and J. W. Sutherland. 2008. An exploration of measures of social sustainability and their application to supply chain decisions. Journal of Cleaner Production **16**:1688-1698.

Ijomah, W., C. A. McMahon, G. P. Hammond, and S. T. Newman. 2007. Development of design guidelines to support sustainable manufacuring. Robotics and Computer-Integrated Manufacturing **23**:712-719.

Ilgin, M. A. and S. M. Gupta. 2009. Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art. Journal of Environmental Management **91**:563-591.

Isenmann, R., C. Bey, and M. Welter. 2007. Online reporting for sustainability issues. Business Strategy and the Environment **16**:487-501.

ISO. 2005. ISO 9000:2005, Quality management systems -- Fundamentals and vocabulary. International Organization for Standardization.

Jackson, T. 2005. Live Better by Consuming Less?: Is There a "Double Dividend" in Sustainable Consumption? Journal of Industrial Ecology **9**:19-36.

Jasch, C. 2000. Environmental performance evaluation and indicators. Journal of Cleaner Production **8**:79-88.

Jasch, C. 2003. The use of Environmental Management Accounting (EMA) for identifying environmental costs. Journal of Cleaner Production **11**:667-676.

Jasch, C. 2006. How to perform an environmental management cost assessment in one day. Journal of Cleaner Production **14**:1194-1213.

Jasch, C. and A. Lavicka. 2006. Pilot project on sustainability management accounting with the Styrian automobile cluster. Journal of Cleaner Production **14**:1214-1227.

Jayne, M. R. and G. Skerratt. 2003. Socially responsible investment in the UK—criteria that are used to evaluate suitability. Corporate Social Responsibility and Environmental Management **10**:1-11.

Johansson, G. 2002. Success factors for the integration og ecodesing in product development - a review of the state-of-the-art. Environmental Management and Health **13**:98-107.

Jonker, J. and D. Foster. 2002. Stakeholder excellence? Framing the evolution and complexity of a stakeholder perspective of the firm. Corporate Social Responsibility and Environmental Management **9**:187-195.

Kaenzig, J. and R. Wüstenhagen. 2010. The Effect of Life Cycle Cost Information on Consumer Investment Decisions Regarding Eco-Innovation. Journal of Industrial Ecology **14**:121-136.

Karlsson, C. 2009. Researching Operations Management. Taylor & Francis.

Karlsson, R. and C. Luttropp. 2006. EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the papers in this special issue. Journal of Cleaner Production **14**:1291-1298.

Kjaerheim, G. 2005. Cleaner production and sustainability. Journal of Cleaner Production **13**:329-339.

Koch, L. and N. A. Ashford. 2006. Rethinking the role of information in chemicals policy: implications for TSCA and REACH. Journal of Cleaner Production **14**:31-46.

Koellner, T., S. Suh, O. Weber, C. Moser, and R. W. Scholz. 2007. Environmental Impacts of Conventional and Sustainable Investment Funds Compared Using Input-Output Life-Cycle Assessment. Journal of Industrial Ecology **11**:41-60.

Kong, N., O. Salzmann, U. Steger, and A. Ionescu-Somers. 2002. Moving Business/Industry Towards Sustainable Consumption:: The Role of NGOs. European Management Journal **20**:109-127.

Koplin, J., S. Seuring, and M. Mesterharm. 2007. Incorporating sustainability into supply management in the automotive industry - the case of the Volkswagen AG. Journal of Cleaner Production **15**:1053-1062.

Kovács, G. 2008. Corporate environmental responsibility in the supply chain. Journal of Cleaner Production **16**:1571-1578.

Krucken, L. and A. Meroni. 2006. Building stakeholder networks to develop and deliver product-service-systems: practical experiences on elaborating pro-active materials for communication. Journal of Cleaner Production **14**:1502-1508.

Kuhn, T. 1970. The structure of scientific revolutions. University of Chicago Press, Chicago.

LaFrance, J. and M. Lehmann. 2005. Corporate awakening – why (some) corporations embrace public–private partnerships. Business Strategy and the Environment **14**:216-229.

Lane, B. and S. Potter. 2007. The adoption of cleaner vehicles in the UK: exploring the consumer attitude-action gap. Journal of Cleaner Production **15**:1085-1092.

Lankoski, L. 2008. Corporate responsibility activities and economic performance: a theory of why and how they are connected. Business Strategy and the Environment **17**:536-547.

Larsen, L. B. 2000. Strategic implication of environmental reporting. Corporate Environmental Strategy **7**:276-287.

Le Pochat, S., G. Bertoluci, and D. Froelich. 2007. Integrating ecodesign by conducting changes in SMEs. Journal of Cleaner Production **15**:671-680.

Lee, Y. W., D. M. Strong, B. K. Kahn, and R. Y. Wang. 2002. AIMQ: a methodology for information quality assessment. Information & Management **40**:133-146.

Leire, C. and Å. Thidell. 2005. Product-related environmental information to guide consumer purchases - a review and analysis of research on perceptions, understanding and use among Nordic consumers. Journal of Cleaner Production **13**:1061-1070.

Lenox, M. J. and J. Nash. 2003. Industry self-regulation and adverse selection: a comparison across four trade association programs. Business Strategy and the Environment **12**:343-356.

Li, L. and K. Geiser. 2005. Environmentally responsible public procurement (ERPP) and its implications for integrated product policy (IPP). Journal of Cleaner Production **13**:705-715.

Lindahl, M. 2005. Engineering Designers' Requirements on design for environment methods and tools. Royal Institute of Technology, KTH, Stockholm.

Lindahl, M. 2006. Engineering designers' experience of design for environment methods and tools - Requirement definitions from an interview study. Journal of Cleaner Production **14**:487-496.

Lindell, M. and N. Karagozoglu. 2001. Corporate environmental behaviour – a comparison between Nordic and US firms. Business Strategy and the Environment **10**:38-52.

Line, M., H. Hawley, and R. Krut. 2002. The Development of Global Environmental and Social Reporting. Corporate Environmental Strategy **9**:69-78.

Linnenluecke, M. K., S. V. Russell, and A. Griffiths. 2009. Subcultures and sustainability practices: the impact on understanding corporate sustainability. Business Strategy and the Environment **18**:432-452.

Lofthouse, V. 2006. Ecodesign tools for designers: defining the requirements. Journal of Cleaner Production **14**:1386-1395.

Lundgren, M. and B. Catasus. 2000. The banks' impact on the natural environment - on the space between 'what is' and 'what if'. Business Strategy and the Environment **9**:186.

Lundteigen, M. A. 2009. Safety instrumented systems in the oil and gas industry: Concepts and methods for saefty and reliabilty assessments in design and operation. NTNU, Norwegian University of Science and Technology Trondheim.

Lundteigen, M. A. 2009:9. Safety instrumented systems in the oil and gas industry: Concepts and methods for safety and reliability assessments in design and operation. Norwegian University of Science and Technology (NTNU), Trondheim.

Luttropp, C. and J. Lagerstedt. 2006. EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development. Journal of Cleaner Production **14**:1396-1408.

Madsen, H. and J. P. Ulhøi. 2001. Integrating environmental and stakeholder management. Business Strategy and the Environment **10**:77-88.

Manzini, E. and C. Vezzoli. 2003. A strategic design approach to develop sustainable product service systems: examples taken from the [`]environmentally friendly innovation' Italian prize. Journal of Cleaner Production **11**:851-857.

Marchand, A. and S. Walker. 2008. Product development and responsible consumption: designing alternatives for sustainable lifestyles. Journal of Cleaner Production **16**:1163-1169.

Maxwell, D., W. Sheate, and R. van der Vorst. 2006. Functional and systems aspects of the sustainable product and service development approach for industry. Journal of Cleaner Production **14**:1466-1479.

Maxwell, D. and R. van der Vorst. 2003. Developing sustainable products and services. Journal of Cleaner Production **11**:883-895.

McAloone, T. and N. Bey. 2009. Environmental improvement through product development: A guide. Danish Environmental Protection Agency, Copenhagen, Denmark

McDonald, S. and C. J. Oates. 2006a. Sustainability: Consumer Perceptions and Marketing Strategies. Business Strategy and the Environment **15**:157-170.

McDonald, S. S. and C. J. C. Oates. 2006b. Sustainability: Consumer Perceptions and Marketing Strategies. Business Strategy and the Environment **15**:157.

McMurtrie, T. 2005. Factors influencing the publication of social performance information: an Australian case study. Corporate Social Responsibility and Environmental Management **12**:129-143.

McWhinney, M., A. Fanara, R. Clark, C. Hershberg, R. Schmeltz, and J. Roberson. 2005. ENERGY STAR product specification development framework: using data and analysis to make program decisions. Energy Policy **33**:1613-1625.

Meredith, J. 1998. Building operations management theory through case and field research. Journal of Operations Management **16**:441-454.

Merriam-Webster. 2011a. "Methodology", Cited online 23. November. Merriam-Webster Online.

Merriam-Webster. 2011b. "Research", Cited online 23. November. Merriam-Webster Online.

Meyer, A. 2001. What's in it for the customers? Successfully marketing green clothes. Business Strategy and the Environment **10**:317.

Michelini, R. C. and R. P. Razzoli. 2004. Product-service eco-design: Knowledge-based infrastructures. Journal of Cleaner Production **12**:415-428.

Miles, M. B. and A. M. Huberman. 1994. Qualitative Data Analyises, an expanded source book. Second Edition edition. Sage Publications Inc.

Minoli, D. M. and J. N. B. Bell. 2003. Insurance as an alternative environmental regulator: findings from a retrospective pollution claims survey. Business Strategy and the Environment **12**:107-117.

Moffat, A. and A. Auer. 2006. Corporate Environmental Innovation (CEI): a government initiative to support corporate sustainability leadership. Journal of Cleaner Production **14**:589-600.

Mont, O. and A. Plepys. 2008. Sustainable consumption progress: should we be proud or alarmed? Journal of Cleaner Production **16**:531-537.

Mont, O. K. 2002. Clarifying the concept of product-service system. Journal of Cleaner Production **10**:237-245.

Moore, S. B. and S. L. Manring. 2009. Strategy development in small and medium sized enterprises for sustainability and increased value creation. Journal of Cleaner Production **17**:276-282.

Morhardt, J. E. 2010. Corporate social responsibility and sustainability reporting on the Internet. Business Strategy and the Environment **19**:436-452.

Morhardt, J. E., S. Baird, and K. Freeman. 2002. Scoring corporate environmental and sustainability reports using GRI 2000, ISO 14031 and other criteria. Corporate Social Responsibility and Environmental Management **9**:215-233.

Nawrocka, D. and T. Parker. 2009. Finding the connection: environmental management systems and environmental performance. Journal of Cleaner Production **17**:601-607.

Nemcsicsné Zsóka, Á. 2008. Consistency and "awareness gaps" in the environmental behaviour of Hungarian companies. Journal of Cleaner Production **16**:322-329.

Nijhof, A., O. Fisscher, and J. K. Looise. 2002. Inclusive innovation: a research project on the inclusion of social responsibility. Corporate Social Responsibility and Environmental Management **9**:83-90.

Nissinen, A., J. Grönroos, E. Heiskanen, A. Honkanen, J.-M. Katajajuuri, S. Kurppa, T. Mäkinen, I. Mäenpää, J. Seppälä, P. Timonen, K. Usva, Y. Virtanen, and P. Voutilainen. 2007. Developing benchmarks for consumer-oriented life cycle assessment-based environmental information on products, services and consumption patterns. Journal of Cleaner Production **15**:538-549.

Nonaka, I. 1994. A Dynamic Theory of Organizational Knowledge Creation. Organization Science **5**:14-37.

Nordheim, E. and G. Barrasso. 2007. Sustainable development indicators of the European aluminium industry. Journal of Cleaner Production **15**:275-279.

Ny, H., S. Hallstedt, K.-H. Robèrt, and G. Broman. 2008. Introducing Templates for Sustainable Product Development. Journal of Industrial Ecology **12**:600-623.

O'Connor, M. and J. H. Spangenberg. 2008. A methodology for CSR reporting: assuring a representative diversity of indicators across stakeholders, scales, sites and performance issues. Journal of Cleaner Production **16**:1399-1415.

O'Rourke, D. 2005. Market Movements: Nongovernmental Organization Strategies to Influence Global Production and Consumption. Journal of Industrial Ecology **9**:115-128.

Olsthoorn, X., D. Tyteca, W. Wehrmeyer, and M. Wagner. 2001. Environmental indicators for business: a review of the literature and standardisation methods. Journal of Cleaner Production **9**:453-463.

Oxley Green, A. and L. Hunton-Clarke. 2003. A typology of stakeholder participation for company environmental decision-making. Business Strategy and the Environment **12**:292-299.

Paulraj, A. 2009. Environmental motivations: a classification scheme and its impact on environmental strategies and practices. Business Strategy and the Environment **18**:453-468.

Peattie, K. 2001. Golden goose or wild goose? The hunt for the green consumer. Business Strategy and the Environment **10**:187.

Pedersen, E. R. and P. Neergaard. 2006. Caveat emptor – let the buyer beware! environmental labelling and the limitations of 'green' consumerism. Business Strategy and the Environment **15**:15-29.

Piplani, R., N. Pujawan, and S. Ray. 2008. Sustainable supply chain management. International Journal of Production Economics **111**:193-194.

Plaza-beda, J. A., J. Burgos-Jimnez, D. A. Vazquez, and C. Liston-Heyes. 2009. The 'win-win' paradigm and stakeholder integration. Business Strategy and the Environment **18**:487.

Plaza-Ubeda, J. A., J. Burgos-Jimnez, D. A. Vazquez, and C. Liston-Heyes. 2009. The 'win-win' paradigm and stakeholder integration. Business Strategy and the Environment **18**:487.

Polonsky, M. J. 1995. A stakeholder theory apporach to designing environmental marketing strategy. The Journal of Buisness & Industrial Marketing **10**:29-45.

Polonsky, M. J. and J. A. Ottman. 1998. Exploratory examination of whether marketers include stakeholders in the green new product development process. Journal of Cleaner Production **6**:269-275.

Prado-Lorenzo, J.-M., I. Gallego-Alvarez, and I. M. Garcia-Sanchez. 2009. Stakeholder engagement and corporate social responsibility reporting: the ownership structure effect. Corporate Social Responsibility and Environmental Management **16**:94-107.

Prakash, A. A. 2002. Green marketing, public policy and managerial strategies. Business Strategy and the Environment **11**:285.

Preuss, L. L. 2005. Rhetoric and reality of corporate greening: a view from the supply chain management function. Business Strategy and the Environment **14**:123.

Reserach-Council. 2011. The Reserach Council's vision and mandate, Cited 23. november. The Reseach Council of Norway.

Ringen, G. 2010. Organizational learning and knowledge in the Norwegian Automotive Supplier Industry. Norwegian University of Science and Technology.

Robèrt, K. H., B. Schmidt-Bleek, J. Aloisi de Larderel, G. Basile, J. L. Jansen, R. Kuehr, P. Price Thomas, M. Suzuki, P. Hawken, and M. Wackernagel. 2002. Strategic sustainable development -- selection, design and synergies of applied tools. Journal of Cleaner Production **10**:197-214.

Rock, M. T., P. L. Lim, and D. P. Angel. 2006. Impact of Firm-Based Environmental Standards on Subsidiaries and Their Suppliers: Evidence from Motorola-Penang. Journal of Industrial Ecology **10**:257-278.

Rogers, P. P., K. F. Jalal, and J. A. Boyd. 2008. An Introduction to Sustainable Development. Earthscan, UK.

Rosen, C. M., S. L. Beckman, and J. Bercovitz. 2002. The Role of Voluntary Industry Standards in Environmental Supply-Chain Management. Journal of Industrial Ecology **6**:103-123.

Rotheroe, N., M. Keenlyside, and L. Coates. 2003. Local agenda 21; articulating the meaning of sustainable development at the level of the individual enterprise. Journal of Cleaner Production **11**:537-548.

Roy, M.-J., O. Boiral, and D. Lagacé. 2001. Environmental commitment and manufacturing excellence: a comparative study within Canadian industry. Business Strategy and the Environment **10**:257-268.

Roy, M.-J. and F. Thérin. 2008. Knowledge acquisition and environmental commitment in SMEs. Corporate Social Responsibility and Environmental Management **15**:249-259.

Rubik, F. and G. Scholl. 2002. Integrated Product Policy (IPP) in Europe--a development model and some impressions. Journal of Cleaner Production **10**:507-515.

Salaün, Y. and K. Flores. 2001. Information quality:: meeting the needs of the consumer. International Journal of Information Management **21**:21-37.

Sanne, C. 2002. Willing consumers--or locked-in? Policies for a sustainable consumption. Ecological Economics **42**:273-287.

Schmidt, M. and R. Schwegler. 2008. A recursive ecological indicator system for the supply chain of a company. Journal of Cleaner Production **16**:1658-1664.

Schrader, U. 2006. Ignorant advice – customer advisory service for ethical investment funds. Business Strategy and the Environment **15**:200-214.

Scott Marshall, R. and D. Brown. 2003. Corporate environmental reporting: what's in a metric? Business Strategy and the Environment **12**:87-106.

Seuring, S. 2004a. Industrial ecology, life cycles, supply chains: differences and interrelations. Business Strategy and the Environment **13**:306-319.

Seuring, S. and M. Müller. 2008. From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production **16**:1699-1710.

Seuring, S., J. Sarkis, M. Müller, and P. Rao. 2008. Sustainability and supply chain management - An introduction to the special issue. Journal of Cleaner Production **16**:1545-1551.

Seuring, S. S. 2004b. Industrial ecology, life cycles, supply chains: differences and interrelations. Business Strategy and the Environment **13**:306.

SFI-Norman. 2008. Project Description of the "Design Factory" (2008).

SFI-Norman. 2011. webpage, accessed November 2011.

Sharfman, M. P. M., T. M. T. Shaft, and R. P. R. Anex. 2009. The road to cooperative supply-chain environmental management: trust and uncertainty among pro-active firms. Business Strategy and the Environment **18**:1.

Solèr, C., K. Bergstrm, and H. Shanahan. 2010. Green supply chains and the missing link between environmental information and practice. Business Strategy and the Environment **19**:14.

Springett, D. D. 2003. Business conceptions of sustainable development: a perspective from critical theory. Business Strategy and the Environment **12**:71.

Srivastava, S. K. 2007. Green supply-chain management: A state-of-the-art literature review. International Journal of Management Reviews **9**:53-80.

Stafford, E. R., M. J. Polonsky, and C. L. Hartman. 2000. Environmental NGO–business collaboration and strategic bridging: a case analysis of the Greenpeace–Foron Alliance. Business Strategy and the Environment **9**:122-135.

Steen, B., A. Gärling, A.-M. Imrell, and K. Sanne. 2008. Development of interpretation keys for environmental product declarations. Journal of Cleaner Production **16**:598-604.

Steger, U., C. Schindel, and H. Krapf. 2002. The experience of EMAS in three European countries: a cultural and competitive analysis. Business Strategy and the Environment **11**:32.

Subramanian, R., B. Talbot, and S. Gupta. 2010. An Approach to Integrating Environmental Considerations Within Managerial Decision-Making. Journal of Industrial Ecology **14**:378-398.

Sundkvist, Å. and G. Finnveden. 2007. Stakeholder needs study on indicators for IPP (Integrated Product Policy). Journal of Cleaner Production **15**:323-326.

Tagesson, T., V. Blank, P. Broberg, and S.-O. Collin. 2009. What explains the extent and content of social and environmental disclosures on corporate websites: a study of social and environmental reporting in Swedish listed corporations. Corporate Social Responsibility and Environmental Management **16**:352-364.

Thun, J.-H. and A. Muller. 2010. An empirical analysis of green supply chain management in the German automotive industry. Business Strategy and the Environment **19**:119.

Tingström, J., L. Swanström, and R. Karlsson. 2006. Sustainability management in product development projects - the ABB experience. Journal of Cleaner Production **14**:1377-1385.

Tsoulfas, G. T. and C. P. Pappis. 2008. A model for supply chains environmental performance analysis and decision making. Journal of Cleaner Production **16**:1647-1657.

Tukker, A. 2006. Identifying Priorities for Environmental Product Policy. Journal of Industrial Ecology **10**:1-4.

Tukker, A., M. J. Cohen, K. Hubacek, and O. Mont. 2010. The Impacts of Household Consumption and Options for Change. Journal of Industrial Ecology **14**:13-30.

Tukker, A., S. Emmert, M. Charter, C. Vezzoli, E. Sto, M. Munch Andersen, T. Geerken, U. Tischner, and S. Lahlou. 2008. Fostering change to sustainable consumption and production: an evidence based view. Journal of Cleaner Production **16**:1218-1225.

Törnebohm, H. 1974. Paradigm i vetenskapernas värld och vetenskapsteorin. University of Gothenburg Press, Gothenburg.

Ulrich, K. D. and S. D. Eppinger. 2008. Product Design and Development. Fourth edition. McGraw-Hill Higher Education, New York, USA.

UNEP. 1987. Our Common Future. Oxford Press.

United Nations Environment Programme, T. D. 2009. Design for Sustainability. A step-by-step approach. United Nations Environment Programme.

Uotila, T. and H. Melkas. 2007. Quality of data, information and knowledge in regional foresight processes. Futures **39**:1117-1130.

van Hemel, C. and J. Cramer. 2002. Barriers and stimuli for ecodesign in SMEs. Journal of Cleaner Production **10**:439-453.

van Huijstee, M. and P. Glasbergen. 2008. The practice of stakeholder dialogue between multinationals and NGOs. Corporate Social Responsibility and Environmental Management **15**:298-310.

van Nes, N. and J. Cramer. 2006. Product lifetime optimization: a challenging strategy towards more sustainable consumption patterns. Journal of Cleaner Production **14**:1307-1318.

Verganti, R. 2008. Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda. The Journal of Product Innovation Management **25**:436-456.

Verganti, R. 2009. Design-driven innovation. Changing the rules of competition by radically innovating what things mean. Harvard Business Press, Boston, Massachusetts.

Vezzoli, C. and E. Manzini. 2008. Design for Environmental Sustainability. Springer.

Voss, C., N. Tsikriktsis, and M. Frolich. 2002. Case Research in Operations Management. International Journal of Operations & Production Management **22**:195-219.

Waage, S. A. 2007. Re-considering product design: a practical "road-map" for integration of sustainability issues. Journal of Cleaner Production **15**:638-649.

Waage, S. A., K. Geiser, F. Irwin, A. B. Weissman, M. D. Bertolucci, P. Fisk, G. Basile, S. Cowan, H. Cauley, and A. McPherson. 2005. Fitting together the building blocks for sustainability: a revised model for integrating ecological, social, and financial factors into business decision-making. Journal of Cleaner Production **13**:1145-1163.

Walker, H., L. Di Sisto, and D. McBain. 2008. Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. Journal of Purchasing and Supply Management **14**:69-85.

Waygood, S. and W. Wehrmeyer. 2003. A critical assessment of how non-governmental organizations use the capital markets to achieve their aims: a UK study. Business Strategy and the Environment **12**:372-385.

Weber, O., M. Fenchel, and R. W. Scholz. 2008. Empirical analysis of the integration of environmental risks into the credit risk management process of European banks. Business Strategy and the Environment **17**:149-159.

Welford, R., C. Chan, and M. Man. 2008. Priorities for corporate social responsibility: a survey of businesses and their stakeholders. Corporate Social Responsibility and Environmental Management **15**:52-62.

Wells, P. and R. J. Orsato. 2005. Redesigning the Industrial Ecology of the Automobile. Journal of Industrial Ecology **9**:15-30.

Wiedmann, T. O., M. Lenzen, and J. R. Barrett. 2009. Companies on the Scale. Journal of Industrial Ecology **13**:361-383.

Wikipedia. 2011. "Research", Cited 23. November.

Wilson, C., I. D. Williams, and S. Kemp. 2010. Compliance with producer responsibility legislation: experiences from UK small and medium-sized enterprises. Business Strategy and the Environment:n/a-n/a.

Wimmer, W., R. Zust, and K.-M. Lee. 2004. ECODESIGN Implementation. Springer.

Yakhou, M. and V. P. Dorweiler. 2004. Environmental accounting: an essential component of business strategy. Business Strategy and the Environment **13**:65-77.

Yin, R. K. 2009. Case Study Research, Design and Methods. Fourth Edition edition. Sage Publications Inc.

Young, A. and A. Kielkiewicz-Young. 2001. Sustainable Supply Network Management. Corporate Environmental Strategy **8**:260-268.

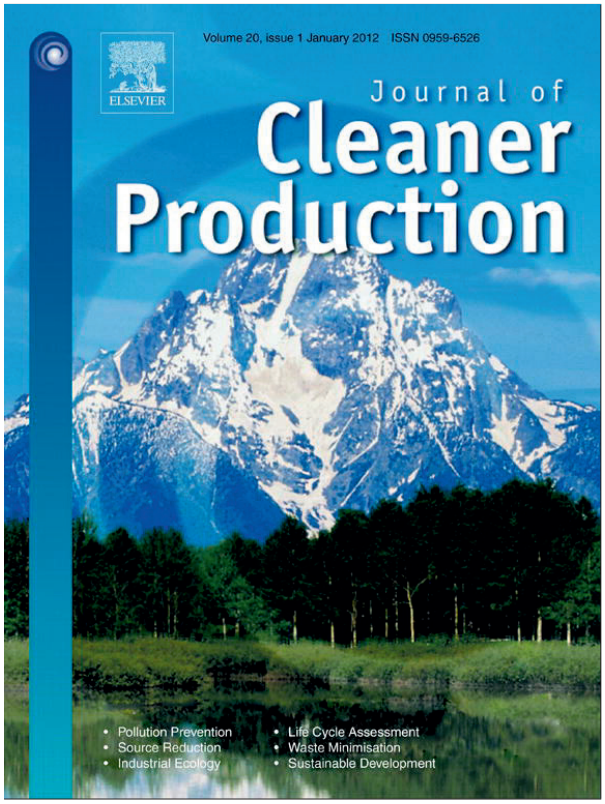
Zackrisson, M., C. Rocha, K. Christiansen, and A. Jarnehammar. 2008. Stepwise environmental product declarations: ten SME case studies. Journal of Cleaner Production **16**:1872-1886.

Zhu, Q., J. Sarkis, and K.-h. Lai. 2007. Green supply chain management: pressures, practices and performance within the Chinese automobile industry. Journal of Cleaner Production **15**:1041-1052.

Zins, C. 2007. Conceptual Approaches for Defining Data, Information and Knowledge. Journal of the American Society for Information Science and Technology **58**:479-493.

Part IV: Results – The appended articles

Paper I



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Environmental information from stakeholders supporting product development

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ABSTRACT

This article presents the results from an in-depth single case study in the Norwegian manufacturing industry. The scope of the research has been to identify, collect, and compile product development relevant environmental information from the firm's external stakeholders and compare this with internal stakeholders' knowledge on the same issue. Main results yield a substantial gap between environmental information availability and environmental information knowledge within this firm, partly due to limited stakeholder collaboration. The understanding of information usefulness was found to be affected by business priorities and goals, internal competence, in addition to function and professional training. The competent use and exploitation of relevant environmental information in product development has the potential to add value to products beyond functionality, quality, and cost, and hence in general enhance firms' competitiveness.

1. Introduction

Increasing pressure from key stakeholders is forcing firms to change their business performance by not only focusing on financial value creation, but also on value creation in ecological and social terms (Cramer, 2002). Tougher market competition, globalization of the economy, changing human and societal values, increasing transparency, and new forms of partnerships between firms and other organizations are some trends that are expected to further change the playing fields of firms (Elkington, 1998). In terms of product development, the shift in environmental policies and laws pertaining to products puts further pressures on firms to develop more environmentally friendly products (Maxwell and van der Vorst, 2003).

In ecodesign, researchers have developed tools and methodologies for environmental considerations of products (Baumann et al., 2002; Byggeth and Hochschorner, 2006; Karlsson and Luttropp, 2006) with a predominant product and process data focus. As product development and design may be regarded as an information transformation process (Hubka et al., 1988) or an information process, relevant environmental information (EI) may be considered a prerequisite for making informed decisions in the various stages of product development. EI has to be "collected, compiled, and disseminated" (Erlandsson and Tillman, 2009). Relevant information may be found among the different actors of a system. Consequently, dealing with environmental issues on the level of product design and manufacturing only, or on the level of a single firm, is insufficient (Baumann et al., 2002). Other researchers have previously addressed EI in the context of greening the innovation process (Foster and Green, 2000), or EI collection, management, and communication (Erlandsson and Tillman, 2009). EI relevant for supporting product development specifically, as defined in this article, is less explored.

This article aims to address EI in manufacturing firms in a product development context, using stakeholder theory as a research framework. As stakeholders may be loosely described as "*anything influencing or influenced by the firm*" (Freeman, 1984; Donaldson and Preston, 1995), stakeholder theory seems appropriate for addressing EI among the different actors of a system. EI is in this article defined by the authors as: *stakeholder information elements concerning the environment potentially capable of contributing to knowledge in product development*. The goal of EI use in product development is to increase a firm's ability to develop environmentally friendly and commercially viable products. EI in a product development context explicitly includes information beyond internal product and process data. It encompasses information like customers' environmental perception of a product, NGOs' campaigns targeted at environmentally harmful industrial practices, 'intelligence' on competitors' environmental marketing and product portfolio strategies, and upcoming laws and regulations. EI also includes environmental expectations (EE) from firm stakeholders, what firm stakeholders truly want from a product

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and a firm concerning environmental issues. EE are important and integral parts of EI, but are in this article emphasized separately to demonstrate the potential value of also using more EE in product development. EE are often less tangible, less clearly expressed parts of EI, and may also require transformation into performance requirements before being used in product development, e.g. through the use of Quality Function Deployment (QFD) (Andersen and Fagerhaug, 2002).

Through a case study, it will be explored to what extent external stakeholders have EI including EE relevant to product development, and to what extent the firm is knowledgeable about this information. Hence, the purpose of this article is to investigate if the stakeholder approach is viable for the identification, collection, and compilation of relevant EI including EE, and to clarify the EI including EE structure among various stakeholders. A theoretical background to support the case study will first be described, before the article summarizes results, main conclusions, as well as propositions for future research.

2. Research framework

Information is required to make knowledge based decisions in product development; hence our research partly draws on the assumption that manufacturing firms may experience synergies from identification and subsequent use of more relevant EI including EE in product development. On one level, relevant information for product development is available from external stakeholders. On another level, information is received and interpreted by different internal stakeholders. We wish to explore what information is available "out there" and compare it to in-house knowledge as shown in Fig. 1.The research questions that will be explored in a product development context are:

- Level 1: What EI, including EE, is available from external stakeholders?
- Level 2: What EI, including EE, does the firm know about?

Our research framework for studying EI including EE in product development in manufacturing firms elaborates and builds on previous work by Foster and Green (Foster and Green, 2000) and Erlandsson and Tillman (Erlandsson and Tillman, 2009), and is based on stakeholder theory (Freeman, 1984).

3. Theoretical background

As an introduction to the exploration of scientific literature supporting our case study approach, we will begin by clarifying the nature of information and knowledge. Data, information, and knowledge are often viewed as being part of a sequential order: data as the raw material for information, and information being the raw material for knowledge (Zins, 2007). Information may broadly be regarded as what people need to be able to carry out their work (Braganza, 2004), others describe information as an element describing a fact (Hicks et al., 2002). According to Nonaka, information can loosely be described as a flow of messages, whereas knowledge is created and organized from the information flow, strongly influenced by and rooted in the commitments and beliefs of the holder (Nonaka, 1994). Hence, identified, collected, and compiled EI including EE have the potential to contribute to knowledge through being utilized.

3.1. What EI and EE are available from external stakeholders?

The general importance of stakeholder theory was first introduced into strategic management literature through Freeman's original work in 1984 (Freeman, 1984), and has later gained great popularity and importance. Stakeholders may be defined as "*any group or individual who can affect or is affected by the achievement of the firm's objective*" (Freeman, 1984), or "*organizations, institutions, or persons affected by or with a vested interest in the organization and its business processes who hold expectations with regard to products or services delivered by the organization through the* business processes that produce these products or services, and support and enable the production of them (Andersen, 1999)". Commonly mentioned external stakeholder groups are shareholders, financial institutions, competitors, customers, NGOs, media, government, industry associations, academia, and suppliers. Internal stakeholders include management, employees, and unions (Andersen and Fagerhaug, 2002). The relationship between a firm and its stakeholders is characterized by a mutual exchange process of money, goods, information, and expectations (Andersen and Fagerhaug, 2002). Our interest is the information and expectations flows on environmental issues relevant to product development.

Literature suggests approaching the stakeholders directly to identify true insights (Andersen and Fagerhaug, 2002). Obtaining the required information may however be a challenge, as there are large numbers of stakeholders involved, and the majority of these are not within the firm's control (Erlandsson and Tillman, 2009). The further upstream or downstream in the value chain these stakeholders are situated, the more difficult it may be to interact and obtain relevant information. Some firms may not be willing to share information with other stakeholders in the value chain for proprietary reasons (Waage, 2007). Also, firms may be unaware of

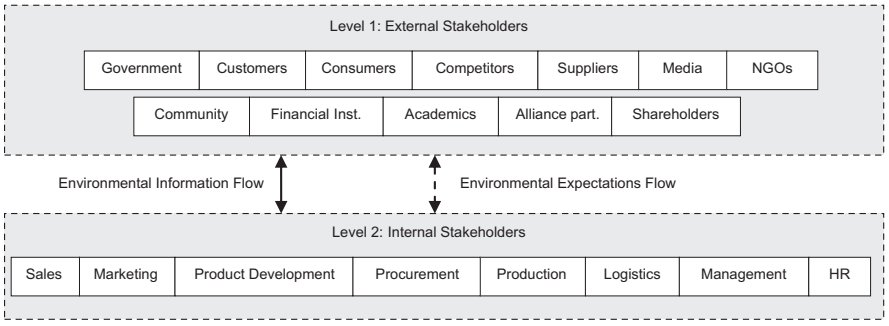

Fig. 1. EI and EE flow among stakeholders.

which EI including EE could benefit them. Hence, we believe there must be an incentive for firm stakeholders to successfully exchange information, for example the potential of increased firm competitiveness through environmental improvements (Porter and van der Linde, 1995).

One way of overcoming these obstacles may be to involve external stakeholders more directly in the firm business processes. Such involvement in product development may be both situation and firm specific. Traditionally, stakeholders have not been directly involved in the generation of new ideas (Polonsky and Ottman, 1998), although supplier and consumer collaboration in product development is becoming increasingly common (Polonsky and Ottman, 1998; Hoffmann, 2007; Darnall et al., 2008). A model for stakeholder "*informative*", "*consultative*", or "*decisional*" participation may provide the opportunity for generating the required EI including EE (Oxley Green and Hunton-Clarke, 2003). Informative participation involves information transformation from one body to another. Consultative participation involves more involvement; stakeholders are asked for their opinion on specific issues. Decisional participation refers to when the stakeholders participate in the actual decision making process. Decisional participation is more likely to yield long-term success as decisions are mutually agreed upon and thereby more socially acceptable (Oxley Green and Hunton-Clarke, 2003).

3.2. What do firms know?

A firm is likely to possess a certain degree of knowledge about its stakeholders' performance and expectations through meetings, formal and in-formal communication, internet, news, regulations, as well as supply chain management, marketing, and benchmarking activities. The way a firm distributes such EI including EE within the organization and thus contributes to the possible creation of knowledge, has the potential to affect actions and priorities in product development.

Stakeholder pressure is exerted and received at different levels in a firm (Delmas and Toffel, 2004). Community pressure may typically be targeted at plant level, whereas shareholder pressure may be targeted at corporate level. The way internal stakeholders react may depend on the recipient's organizational belonging. For example, engineers may perceive environmental pressure differently than legal departments. Legal departments are likely to interpret pressure in terms of risk, liability, and lawsuits, whereas engineering designers may perceive environmental pressure as an incentive for creativity. The information source itself may also be part of the cultural framing, in the sense that the managers' perception of the source may influence the way managers adopt their environmental practices (Henriques and Sadorsky, 1999; Delmas and Toffel, 2004). In this perspective, information from shareholders is likely to be viewed as more important to product development than NGO information concerning the same matter.

Individuals within an organization constantly work to recreate and fit the world into their own perspectives (Nonaka, 1994), hence their personal values, beliefs, and knowledge on environmental issues will strongly influence how they understand and assess stakeholders' information and requirements. A manager with great knowledge of and commitment to environmental issues is likely to be perceptive and respond to environmental expectations. A manager with less commitment to environmental issues is more likely to overlook or disregard such expectations. Moreover, managerial attitudes and roles as motivators play an important role for the environmental pro-activity of the firm (González-Benito and González-Benito, 2008).

Employees are also affected directly and indirectly by the firm's values, priorities, and actions. Environmental policies and management systems are direct sources of environmental information to be used to guide strategically the development process (Maxwell and van der Vorst, 2003). Other relevant information may be related to materials and chemicals used, pollutants released, energy sources, logistics, and distribution methods (Erlandsson and Tillman, 2009), although predominantly product and process related. In-house environmental performance is also expected to affect employees' actions and priorities. A firm that pollutes the local river is likely to have less environmentally committed employees than firms that continuously work to improve their environmental performance.

Indeed, different people, in different organizational domains, with different attitudes and responsibilities, will look for different sources of information, and employ different ways of searching to satisfy their different needs. They may also be unaware of each other's knowledge and might not see the benefit of nor have the incentive to combine different types of information and knowledge. Increased use and exploitation of such information is expected to be beneficial to the development of more environmentally benign products, and in turn, increased competitiveness.

4. Research design and methodology

Little research exists on EI including EE related to product development, therefore an in-depth exploratory case study in the Norwegian manufacturing industry was chosen. Exploratory case studies are considered strong in early stages of research when variables are still relatively unknown and the phenomenon not completely understood (Karlsson, 2009). A detailed research protocol was developed and discussed with experienced researchers to enhance reliability and validity of the research including: case selection and sampling, pre-visit preparations, on site data collection instruments, who to contact, triangulation, recording, analysis, and communication with the firm.

Case collection and sampling are critically important for case research and include relevance for research questions, if the phenomenon to be studied may appear, and if it is feasible and ethical (Karlsson, 2009). Against this background, we searched for a firm with high environmental standards to ensure that environmental concerns were integral parts of daily business. We also targeted a firm of a certain size in order to be able to study EI including EE in a multiple stakeholder environment. Having in-house product development, logistics, and sales departments was also important so that in-house knowledge on EI including EE were available for study.

In order to explore what EI including EE are available from external stakeholders, we interviewed 1–5 individuals from each stakeholder group, selected in cooperation with the firm to ensure inclusion of the most important ones. 30 external stakeholders within different positions were interviewed to ensure that not only the management perspective was included. The interviews were performed through a combination of direct and telephone interviews in 2010. In addition, marketing material and annual reports etc. were used as additional sources of information.

12 semi-structured interviews were performed within the firm in 2009, six within product development and six within the remaining departments. Representatives from R&D, sales, production, logistics, and management were interviewed to obtain a representative picture on in-house knowledge. *Sales* representatives have firsthand experience with customers and consumers. *Production* has information on internal processes, governmental, and community relations. *Logistics* has valuable information on the firm's extended supply chain. *Management* has information regarding the business setting including shareholders, financial institutions, and alliance partners. And finally, *R&D* was included as

they have information from academia, NGOs, competitors, and most importantly, knowledge as to what kind of information is used as input in decision making processes and evaluations in product development. In addition to semi-structured interviews, document analysis, and direct observations were used for data collection within the firm. The interviews and data collection were spread over time to allow for reflection and to reduce the risk of "going native" (Karlsson, 2009). Repeated visits were made to clarify previous information or to gather more information. To further increase the case study focus, only one product group was studied within the firm.

5. Results

5.1. Firm characteristics

The selected firm is part of a corporation counting six firms, our firm being the largest in terms of sales and revenues. The firm is located in Norway and has a supply base of twenty core suppliers in 10 different countries. Based on revenues of approximately USD 65 million in 2009, more than 90% of the firm's revenues come from the studied product group. The production is fully automated, and annual production volume exceeded 1.2 million units in 2009. The case firm does not produce for stock; hence the production volume is constantly adapted to sales. Their overall goal is to be world number one within its product segment. Reduced cycle time in production and increased efficiency are also important areas for the firm. The case firm employs approximately 100 persons and produces mostly for a global market.

Approximately 5–10% of annual revenues are spent on product development activities, either incremental improvements to existing products, or on new product development (NPD). Incremental improvements are typically driven by production problems, the wish to streamline a particular process in production, or the wish to enter a new market with an existing product. NPD activities are typically driven by strategic decisions to develop new product segments. Development projects are run equally for NPD and improvement projects, but the development activities are limited to existing production technology platforms. Based on interviews, observations, and documents, we find support to characterize the development process as informal and democratic: all employees are encouraged to propose new ideas and projects.

5.2. Interview results and discussions

Information from interviews with external stakeholders together with in-house information was analyzed and compiled according to Fig. 2. Firm level refers to information and expectations regarding environmental practices and issues at production site. Product level information and expectations refers to environmental properties of the product itself.

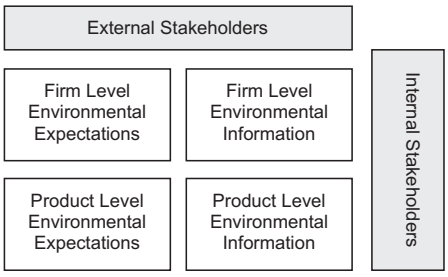

Fig. 2. EI and EE matrix.

Tables 1 and 2 demonstrate the EI including EE potentially relevant to product development. Envisioning a generic product development process (Cross, 2008), the results in Tables 1and 2 may be used as input for the development of environmental product specifications and requirements, in the development of alternative environmentally friendly product schemes, and for choosing between different solutions.

5.2.1. The environmental information gap

Competitors' product portfolios are explored through product benchmarking to obtain information relevant to product development. The firm continuously tears down and examines competitors' products to learn what others are doing, as recommended in literature (Boks and Stevels, 2003). Environmental issues have, however, not been targeted in such activities by the firm, and provides a yet unexploited potential for more EI. In this study, the former competitor interviewed was willing to share a full LCA for a similar product. The LCA clearly identifies which life cycle phases the case firm could target for environmental improvements in product development. Besides, the reported increased customer focus on environmental product performance is a clear signal to the firm to further improve its product through product development. The observed gap between EI availability and EI knowledge in this domain was suggested by the firm to exist due to lack of customer and regulatory demand for EI use in general.

To some extent, this statement was supported by EI results concerning the major national *customer (network-dealer)*; little EI was suggested by the customer. The customer reported solely on a consumer poll concerning the product's use phase, a poll in which environmental issues had not been topic. For confidentiality reasons, only one customer was allowed to participate in this study. Hence, this result could potentially differ if more customers were interviewed on this topic. On the other hand, based on the current results, the firm was very knowledgeable about its customers and no significant EI gap was observed. Main information generating activities described by the case firm included regular sales and management meetings with customers. Contrary to recommendations in literature (Oxley Green and Hunton-Clarke, 2003), the information gathering was described as an ad-hoc informative process by the interviewees, rather than consultative or decisional participation which is likely to yield greater long term success. Another important issue concerns the understanding of information which is dependent on cultural context, personal goals, and profession (Nonaka, 1994; González-Benito and González-Benito, 2008). Hence, sales and management may unintentionally filter out or miss the opportunity of obtaining relevant EI, as they are likely to be mostly occupied with sales numbers, pricing, and delivery. Consequently, a standardization of information generating activities, including EI, could be beneficial to the firm.

Contrary to the reported lack of regulatory demand for EI use, *governmental institutions* provided several statements like "*we expect BAT information to be used in product development*". Statements like this clearly signal that the government expects EI to be used in product development, although this is not yet a strict requirement. As the government is the provider and administrator of EI influential to product development, the national and EC candidate lists on hazardous substances, and pre-regulations on extended producer responsibility for instance, should be relevant when the firm develops environmental product specifications and requirements, or in choosing between different product schemes and solutions. Such EI on *future* regulations may provide the firm with a competitive advantage provided early integration in development activities. The case firm was knowledgeable on a general

Table 1
Environmental information - firm and product level.

Environmental information				
	Firm level: external stakeholders "*Information on…..*"	Product level: external stakeholders "*Information on…..*"	Firm level: in-house knowledge "*information on…..*"	Product level: in-house knowledge "*information on…..*"
Competitors - Largest competitor 1 interview	- Different manufacturing solutions	- Customers' increased focus on environmental issues in general - EOL: the outer part can be recycled; the inner part can be incinerated for energy recovery - Full LCA available for similar product with good result - Different product solutions - LCC which is lower than competitor alternative	- None	- Marketing and sales material on environmental issues publicly accessible on e.g. internet, fairs, and exhibitions
Customers - Largest National Customer 1 interview	- None	- Consumers use scenarios of product in general	- Requirements for standards like ISO 9001, ISO 14001, ISO 14040 - Concerns on environmental issues regarding product content, rather than the product itself - Positive environmental perception of the firm - Customers' environmental standards	- Requirements for product specific certificates - Reclamations from customers - Customers' future product environmental requirements and preferences - Customers' demands to develop more environmentally friendly products - Customers' willingness to pay extra for more environmentally friendly products - Customers' increasingly inquiring about EOL
Consumers 5 interviews	- Perception of firm reputation which increases positively if firm exceeds mandatory requirements on environmental performance	- Requirements for easily accessible EI on product - Preferences for the most environmentally friendly product at equal price - Acceptance of small premium (5–10%) for superior environmental performance - Preferences for color schemes which symbolize the environmental performance of the product	- None	- Product reclamations or problems forwarded from customer
Government - The National Climate and Pollution Agency 2 interviews	- Willingness to assist firms on information on up-coming EC regulations and their implications - BAT[a] and BREF[b] on internet continuously updated with new info - BAT and BREF which are not legally binding but will be used as guidelines in audits - Newsletters on regulations regularly distributed	- National priority list (substitution list) on 30 hazardous substances - EC priority list on forbidden hazardous substances - EC candidate list on hazardous substances	- New regulations (banning of chemicals) - Existing regulations	- New regulations (banning of chemicals) - Existing regulations[c] - Export/import countries' regulations
Community - The municipality 1 interview	- Green papers relevant to the industry - Environmental conditions in local river	- Local discharge data - Regulations for land deposits of production waste	- None	- None
Media - Newspaper, radio/TV 2 interviews	- None	- Relevant issues from internet, new articles, business journals, etc.	- None	- None

(*continued on next page*)

Table 1 (*continued*)

Environmental information				
	Firm level: external stakeholders "*Information on…..*"	Product level: external stakeholders "*Information on…..*"	Firm level: in-house knowledge "*information on…..*"	Product level: in-house knowledge "*information on…..*"
Shareholders - CEO, Shareholder, Board Room Representatives 5 interviews	- Attitudes and values on environmental issues; national environmental requirements not necessarily applied abroad as they might be negative for competition - Attitudes and values on social issues; child labor absolutely unacceptable - Environmental news from environmental institutions owners engage in	- Market material on suppliers and competitors from exhibitions - Attitudes and values on environmental issues; high environmental standards among suppliers is often related to higher quality of materials - Ongoing work to implement green supply chain management standards in the corporation which will apply to all subsidiaries	- Strategic documents concerning environmental issues available on internet and intranet - Environmental technologies from sister firms within corporation	- Experience from customers in other markets the owners are in contact with - Strategic documents concerning environmental issues available on internet and intranet - Attitudes and values on environmental issues; very high cost focus from firm shareholders, environmentally friendly products must also be cost effective - Attitudes and values on environmental issues; positive shareholders if EOL scenario was improved
Suppliers - Material Suppliers 2 interviews	- Suppliers' own environmental stewardship (e.g. EMS, ISO 14001, etc.)	- New materials under development which are more environmentally friendly and have lower solvent content - The wish to work together to develop more environmentally friendly materials - The wish to be first to market with a better environmental approach than competitors - New materials under development that are lighter and stronger and have potential of even lighter end product	- Suppliers' working and environmental conditions - Suppliers' order and housekeeping - Suppliers' ethics - Product Data Sheets, Technical Data Sheets, Material Safety Data Sheets - IMDS (International Material Data System). - Adherence to standards (ISO 9001, 14001, 14040). - Use of hazardous substances in materials from suppliers - New environmental production technologies	- New materials developed by suppliers - Collaboration projects concerned with more environmentally friendly materials
Financial institutions - Banking, Insurance companies 2 interviews	- Checklists for rating firm environmental risk - Green investment funds available from bank - Financial institutions' own environmental stewardship (e.g. EMS, ISO 14001, etc.)	- New insurance product concerned with environmental liability of products soon available as response to stricter EC regulations concerned with extended product responsibility (EPR) - Environmental liability insurance which is expected to become more important in future. Will involve more comprehensive environmental audits of firms and their products	- Financial institutions' own environmental stewardship	- None
Academia - University, College, Research Inst. 3 interviews	- R&D results from other projects	- New materials and EOL handling from other R&D projects	- Innovations within production processes, EOL scenarios and materials (less harmful chemicals) from other research projects or firms - Relevant research articles	- Innovations within EOL scenarios and materials (less harmful chemicals) from other research projects or firms

Table 1 (*continued*)

Environmental information				
	Firm level: external stakeholders "*Information on…..*"	Product level: external stakeholders "*Information on…..*"	Firm level: in-house knowledge "*information on…..*"	Product level: in-house knowledge "*information on…..*"
Alliance partners - Industry Associations, - The Industrial Park 5 interviews	- Breakthroughs in R&D from industry or academia - New and less environmentally harmful materials from newsletters, journals, and conference monitoring - New environmental technologies for production - R&D on recycling of specific materials - News from internet relevant sites - Political signals on new operating constraints for industry segment regarding stricter environmental requirements, taxes, etc.	- Breakthroughs in R&D from industry or academia - New and less environmentally harmful materials from newsletters, journals, and conference monitoring - EOL scenario development within industry - New areas of research funded nationally or internationally giving signals on future priorities and trends - New trends within industry segment	- Environmental issues through knowledge exchange from working within similar projects in other firms	- Environmental issues through knowledge exchange from working within similar projects in other firms
NGOs - Environmental Group 1 interviews	- National action plans concerned with energy use and sources	- None	- None	- None

[a] BAT = Best Available Technology.
[b] BREF = European IPPC Bureau Reference Document.
[c] Includes relevant directives and communication from the European Commission (EC) such as REACH (REACH, 2006), RoHS (RoHS, 2002), IPP (IPP, 2003), IPPC (IPPC, 1996), in addition to national laws and regulations.

level of the usefulness of governmental EI. There was, however, a significant gap concerning the specific regulations relevant to the firm. In this respect, the firm emphasized that they find it hard to keep track of all relevant existing and upcoming regulations as they do not know where to look or what to look for. The government, on the other hand, emphasized the possibility of assisting the firm with such issues.

Consumers (end-users) are important stakeholders as their acceptance of a product means either make or break. For instance, several consumers expressed that they would choose the case firm's product if it was more environmentally friendly at equal price, or they might even accept a small price premium. They also emphasized that such environmental friendliness preferably should be expressed through the product's physical appearance. Such EI directly affects design specifications, concepts, and choices of solutions. The case firm itself had never aggregated consumer information, but had instead relied on brief product level reports (polls) from its customers in which environmental issues were not discussed. This may explain the gap between EI availability and EI knowledge. Caution should, however, be taken when using consumer EI, as consumers tend to be environmentally friendly when asked, but their actions at the purchasing moment show another behavior (Peattie, 2001; Leire and Thidell, 2005). Clearly, this demonstrates the importance of uncovering what consumers really want, through e.g. user centered design activities.

A new land deposit regulation for handling of production scrap is an example of EI from the *local community* which directly affects the case firm. This regulation will prohibit deposits of scrap from the firm's production in years to come. Dealing with this regulation, which the firm was unfamiliar with, will require changes both in manufacturing and product development, e.g. by minimize waste during manufacturing or by using more sustainable materials which are either easily reused or recycled. The use of new materials will require a fundamental redesign of the firm's current product. This is one example of EI which is extremely important for the firm to learn about at the earliest possible convenience, but currently the firm and the local community reported to have little formal or informal contact or collaboration which may account for the present information gap. The community emphasized the possibility of increased firm collaboration.

Media are powerful communication agents, but provided little relevant EI in this case study. The interviews were based on the local newspaper and the national broadcasting cooperation. Media themselves reported to be more interested in presenting other actors' information, including EI, rather than being a source of information themselves by aggregating new information. This case firm is known for its world class fully automated manufacturing process. While reviewing media clips from the last years, it became evident that media focused more on presenting the firm, its radical increase in production volume, as well as new jobs created, rather than being a critical information agent. Hence, the case firm's sporadic cooperation with media is likely to yield positive firm reputation rather than potentially interesting EI.

Shareholders and owners expressed great interest in environmental issues, especially the corporation's CEO who also worked for an independent non-profit NGO aiming at finding solutions to the global climate challenge. Environmental commitment and engagement are likely to motivate the corporation's subsidiaries on environmental issues. EI on the ongoing work to implement green supply chain practices in the entire corporation, for instance, may affect supplier collaboration activities, supplier choice, choice of materials, and possibly product design. This is especially the case if current materials are to be substituted, or if current suppliers are terminated due to poor environmental performance, or new environmental requirements are implemented by the firm. The firm was unfamiliar with this EI, even on management level (excluding CEO). Inadequate information flows either between the firm and its shareholders, or inside the firm itself, may explain this information

Table 2
Environmental expectations at firm and product level.

Environmental expectations				
	Firm level: external stakeholders "*we expect the firm to…..*"	Product level: external stakeholders "*we expect the product to…..*"	Firm level: in-house knowledge "*we expect the firm to…..*"	Product level: in-house knowledge "*we expect the product to…..*"
Competitors - Largest Competitor 1 interview	- Perform better than minimum compliance level with regards to regulations	- Be environmentally favorable compared to competitors' products - Entail reduced fuel consumption during transportation and distribution due to lower weight - Entail responsible handling in product EOL	- Be environmentally favorable compared to competitors' firms - Perform better on overall HSE[a] performance and work conditions for employees - Outperform competitors on price and productivity	- Be environmentally favorable compared to competitors' products - Outperform competitors' products due to more R&D activities and investments
Customers - Largest National Customer 1 interview	- Comply with laws and regulations[b] - Comply with contractual requirements - Have high HSE standards for all employees	- Entail responsible handling in product EOL - Have long lifetime - Be light in weight	- Comply with laws and regulations[b] - Have same high environmental standard as customer - Have high HSE standards for all employees - Have environmentally friendly systems for packaging, systems for return, and reuse of pallets - Have increased supplier and customer collaboration	- Entail responsible handling of product EOL (not all customers) - Have long lifetime - Be light in weight - Have reduced maintenance cost due to lower maintenance requirements - Have reduced fuel consumption during transportation and distribution due to lower weight - Add value to and increase loyalty in product service system - Have lower environmental impact than competitor alternative (based on LCA) - Be more environmentally friendly at equal price
Consumers 5 interviews	- Comply with laws and regulations as minimum - Reduce waste from production - Minimize any emissions from production - Use reliable and trustworthy suppliers - Have safe and healthy work environment for all employees	- Be light in weight and easy to handle - Be made of re-useable or recycled materials - Entail responsible handling in product EOL - Not contain hazardous substances	- To give priority to low cost rather than the environment	- Be light in weight and easy to handle - Be harmless to environment - Have low price rather than being environmentally friendly - Maintain its low price even if it becomes more environmentally friendly
Government - The National Climate and Pollution Agency 2 interviews	- Comply with laws and regulations[b] - Document improvements on environmental issues - Perform better than minimum requirements in discharge permit - Continuously seek substitutions to hazardous chemicals - Work according to IPPC[b] directive - Update and improve work processes according to BAT	- Comply with laws and regulations[b] - Be considered for receiving environmental labeling - Not contain hazardous substances - Use BAT information in new product development	- Comply with laws and regulations[b] - Report environmental performance	- Comply with laws and regulations[b]
Community - The municipality 1 interview	- Comply with laws and regulations[b] - Continuously seek substitutions to hazardous chemicals - Report environmental performance based on requirements	- Become more environmentally friendly - Be made of more recycled materials	- Comply with laws and regulations[b] - Not have harmful emissions or disposals - Have high HSE standards for all employees - Operate in ethical and trustworthy manner	- Be environmentally friendly

Media - Newspaper, radio/TV 2 interviews	- Be an ok work place, be a good firm	- Become more environmentally friendly - Be made of more recycled materials	- Have high HSE standards for all employees	- None
Shareholders - CEO, Shareholder, Board Room Representatives 5 interviews	- Comply with laws and regulations[b] or preferably perform better - Follow corporate CSR[c] and environmental standards - Have high HSE standards for all employees - Continuously work with employees to reduce sick leaves - Implement cost effective environmental measures - Follow corporate CSR standards for supplier selection - Have suppliers with high HSE standards (OSHA 18001, ISO 14001) -Have correspondence between operating and corporate environmental goals - Seek business partners with high environmental standards	- Be within national product requirements - Be within product requirements in export country - Entail responsible handling of product EOL - Contribute positively to environment during production and use - Have obvious environmental advantages - Be made of more environmentally friendly materials if technical specifications are satisfied - Have long lifetime - Avoid pollution - Comply with value chain perspective on environment issues	- Comply with laws and regulations[b] - Follow corporation's environmental profile - Take environmental considerations into account	- Comply with laws and regulations[b] - Let customer and market demands drive product development - Entail responsible handling of product EOL - Be environmentally friendly
Suppliers - Material Suppliers 2 interviews	- Comply with laws and regulations[b] - Be reliable and trustworthy - Behave in manner suitable to front page of nationwide newspapers	- Have long lifetime, increased from today's standard - Be light in weight - Be made out of high quality materials, preferably environmentally friendly materials - Have low maintenance requirements - Be made of reused or recycled materials	- Comply with laws and regulations[b] - Behave in ethical manner in all business relations - Have high HSE standards for all employees	- Have long lifetime - Have reduced fuel consumption during transportation and distribution due to lower weight -Be made environmentally benign regardless of suppliers' materials - Have reduced maintenance cost due to lower maintenance requirements
Financial institutions −Banking, Insurance companies 2 interviews	- Comply with laws and regulations[b] - Avoid environmental risks - Have high HSE standards for all employees - Have good housekeeping	- Not pollute in any phase of products' life cycle - Be environmentally friendly	- Have diffuse expectations	- None
Academia - University, College, Research Inst. 3 interviews	- Comply with laws and regulations[b], preferably perform better - Be ISO 14001 certified or work according to this standard - Manufacture in a sustainable manner - Have high HSE standards for all employees - Have green supply chain management system - Have high CSR standards	- Have cradle to cradle perspective - Continuously be made of more environmentally friendly materials - Entail responsible handling of product EOL - Have LCA to demonstrate environmental impact - Be light in weight to reduce fuel consumption during transportation compared to competitors' products - Be possible to be reused and recycled - Continuously be made with substitution to hazardous chemicals - Be useful to society	- Have diffuse expectations	- None

(*continued on next page*)

Table 2 (*continued*)

Environmental expectations				
	Firm level: external stakeholders "*we expect the firm to…..*"	Product level: external stakeholders "*we expect the product to…..*"	Firm level: in-house knowledge "*we expect the firm to…..*"	Product level: in-house knowledge "*we expect the product to…..*"
Alliance partners - Industry Associations, - The Industrial Park 5 interviews	- Comply with laws and regulations[b], preferably perform better - Be actively concerned with environmental issues - Have life cycle perspective on all work processes - Have high HSE standards for all employees - Handle production waste in a responsible manner -Have good housekeeping - Have deposit system for scrapped products	- Be made with a life cycle perspective and be environmentally friendly - Entail responsible handling of product EOL - Be useful with a minimum of environmental footprint - Be made of less environmentally harmful materials - Be easy to assemble and disassemble - Have minimized material input - Be made with reduced use of solvents - Have long lifetime - Be lighter in weight than competitor alternative	- Comply with laws and regulations[b] - Have diffuse expectations and little environmental focus	- None
NGOs - Environmental Group 1 interviews	- Have life cycle perspective on all work processes - Optimize environmental actions in value chain perspective - Have energy efficient production processes - Minimize use of fossil energy sources - Minimize use of hazardous chemicals in production - Minimize waste from production - Have environmental performance indicators - Have green supply chain management systems - Have zero emission society as ultimate goal	- Have LCA on product and alternatives - Have minimized use of hazardous chemicals - Documented environmental performance through eco-labeling	- None	- Have environmental advantages over competitors' alternative

[a] HSE = Health, Safety and Environment.
[b] Includes relevant directives and communication from the European Commission (EC) such as REACH (REACH, 2006), RoHS (RoHS, 2002), IPP (IPP, 2003), IPPC (IPPC, 1996), in addition to national laws and regulations.
[c] CSR = Corporate Social Responsibility.

gap. The firm's lack of knowledge on shareholder EI and their proactive attitude is a good example of the importance of actually asking stakeholders what they truly want, also on environmental issues.

On the other hand, the firm was very knowledgeable about EI from its *suppliers*, and only a minor information gap was found. This concerned one of the main suppliers which is currently developing an even lighter material with large environmental benefits in transportation and use phase of the product. As weight is one of the most significant factors contributing to the overall environmental impact of this product, according to the available LCA, implementing the use of this new material may require a redesign of the current product, as well as of the production lines. Besides this EI, the case firm's overall good knowledge on most EI relevant to product development may be attributed to their frequent involvement in various collaboration projects with suppliers. Both parties also highlighted the mutual benefit of increased collaboration to develop new and more environmentally benign materials. Mutual benefits from supplier collaboration in product development as part of green supply chain activities have previously been reported in literature by other researchers (Darnall et al., 2008).

Financial Institutions have the power to directly affect the firm's business situation through demanding a higher insurance premium, withdrawing capital, or refusing to extend loans on poor environmental performers. They can also favor firms by offering lower interest rates based on good performance (Lundgren and Catasus, 2000), e.g. low environmental risk. Relevant EI identified includes for instance checklist for rating firm environmental risk, available green investment funds, and a liability insurance product concerned with stricter EC regulations on extended product responsibility (EPR). Environmental risk checklists may influence both firm and product environmental performance. If current product and/or firm environmental performance are below par, financial institutions may choose to demand a higher premium or interest rates, or even withdraw capital from the firm if the firm's performance is considered damaging to the financial institutions' reputation or carries an unacceptably high risk. Complying with criteria for green investment funds on the other hand may be an excellent way for a firm to demonstrate to the world and its customers its environmental excellence. Currently, product environmental improvements affecting product development is required by the case firm before such environmental excellence is achieved. Finally, EI on the future environmental liability insurance products concerning EPR will affect this case firm as the current product EOL scenario is unresolved. Given this situation, the case firm may be faced with the risk of not getting insurance, or of paying an unacceptably high insurance premium. This situation may be improved by making radical changes to the product. The case firm was, however, not aware of this EI and how it could influence both product development and the firm's financial situation. The idea of financial institutions influencing product development was completely new to our firm, and is here suggested to explain the identified information gap.

Academia's most important contribution may be its potential to forward new and relevant R&D information, as they also explore innovation opportunities beyond the scope of industrial R&D. Academia's role as "knowledge brokers" have also previously been demonstrated in literature (Roy and Thérin, 2008; Bos-Brouwers, 2009). Relevant EI in this domain concerned opportunities and solutions relevant for product EOL handling. No information gap was identified in this domain, most likely due to current and previous collaboration with academia on research projects. The firm emphasized, however, time constraint as an obstacle to pursuing more collaboration.

Alliance partners and the firm have mutual interests in helping each other, and as such, there is a potential for synergies by working together in development projects. Through different fora, the firm's alliance partners access EI on new environmental benign materials, environmental trends within the industry or product segments, political signals on future operating constraints that may be implemented, or EOL scenarios developed within the industry. All this EI has the potential of influencing product development, either on a strategic level or as direct input on the operative level. Presently, our firm had limited knowledge on EI from its alliance partners. This observed gap between EI availability and EI knowledge may be influenced by an observed "we know best" attitude expressed during the interviews, in which the firm does not fully appreciate the potential benefits of closer cooperation with its alliance partners.

The same attitude appeared when discussing *NGOs* in the case firm, which may explain the observed EI gap. In general, NGOs were not considered important by the firm interviewees. On the other hand, the most influential environmental NGO in Norway was quite familiar with the case firm and described the new national action plans concerning energy relevant both to the manufacturing of and the product itself. These action plans may open up new markets to the case firm, markets in which product development activities are necessary. NGOs are becoming increasingly influential in society as a whole, and it is becoming more common to collaborate with NGOs, through inclusion in product development activities, or through establishing long-term relationships to improve the environmental performance (Kong et al., 2002).

5.2.2. The environmental expectations gap

EE is an important part of EI, but often less clearly expressed, less tangible, and requires more effort to obtain. Some expectations are even often forgotten due to their obviousness (Andersen and Fagerhaug, 2002). In this case study, the results demonstrate a substantial gap between EE availability and EE knowledge within the case firm for all stakeholders except *customers*. The good knowledge on customer EE may be explained through sales' frequent formal and informal contact with customers on a weekly basis. Sales apply customized tools and checklists for such contact; these are however, not standardized across the firm but vary as they are based on the sales representatives' individual experience. As all sales representatives had been with the firm since its start-up, they were highly experienced and had developed both formal and tacit knowledge on their customers' expectations, wants, and desires, and were able to express more EE than the customer interviewed. An interesting observation was made; the tools and checklists reviewed did not include any reference to environmental issues. As sales representatives, they were subjected to cultural framing (reference section 3.2). Consequently, they were mostly concerned with sales volumes, price, and delivery aspects, and did not volunteer to discuss environmental issues unless upon customer initiative. Given that EE knowledge within the firm mainly has been acquired through customers' initiative to discuss such issues and not as the result of a deliberate or targeted action by the firm, this result could imply that current EE knowledge on customers is random and inadequate, as not all stakeholders voluntarily report expectations unless upon direct questions (Andersen and Fagerhaug, 2002). However, the fact that only one customer was allowed to participate in this research makes it difficult to retain or reject such a conclusion.

The degree to which this customer knowledge was made accessible to others, including product development, varied greatly. It was observed that sales had product development relevant EE (and EI) which had not been forwarded to product development as sales did not find it important. Such filtering mechanisms are

important, as they enable organizations to see certain issues more clearly by ignoring others, as well as avoid information overload. (Hoffmann, 2007). On the other side, such filtering mechanisms may result in important EE (and EI) being overlooked, or not transferred to others, as this example demonstrates. Generally, information including EE was normally shared in management fora, through ad-hoc corridors meetings, or through minutes of meetings. Since the firm lacks formal tools, checklists, and systems for systematic identification, collection, compilation, and sharing of EE, it is expected that all departments will execute a certain level of filtering, as sales did, dependent on individual motivation as well as firm priorities and strategies.

A great variety of EE available to the firm from other stakeholders was identified as demonstrated in Table 2. On firm level for instance, some stakeholders expected the firm to operate within all relevant laws and regulations as a minimum, whereas others expected the firm to perform above such. As EE are wide-ranging and not always coherent, it is possible to use tools (e.g. Kano model, priority matrixes) to further analyze expectations to differentiate between the important and not so important ones (Andersen and Fagerhaug, 2002). Care should be taken when using these tools; stakeholder theory and belonging tools originate from the management perspective (Donaldson and Preston, 1995), not the product development perspective. Hence, EE considered unimportant on management level may still be highly relevant to product development and vice versa. The governmental expectation to use BAT information in product development, for instance, or NGOs' expectations on eco-labeling may be filtered out in the traditional way of applying these tools, as neither governments nor NGOs are considered among the most important stakeholders in such tools.

The firm being unaware on EE from most stakeholders indicates a lack of interest in the outside world. An important in-firm characteristic was reflected in many of the answers: a sense of self-sufficiency and "we know best" attitude. Being young, with an entrepreneurship conduct, and established on a world patented production technology platform may explain this characteristic. Nevertheless, this attitude will constantly affect the way the firm relates to its surroundings, including stakeholders, and also to what extent stakeholders are considered important to firm and product performance. External stakeholders' EI and EE have never been directly sought, collected, analyzed, or documented in a systematic manner.

5.2.3. *Influencing factors*

Current firm priorities are expected to influence the firm's willingness to search for EI including EE relevant to product development. Product level environmental improvements were reflected in neither strategic nor operational goals, as opposed to firm level environmental improvements. Firm level improvements directly influence the work environment of employees and, as such, are given high priority. As a result, senior management support for product level environmental improvements was reported to be limited, hence relevant EI including EE risk being overlooked or disregarded.

The overall low environmental competence and knowledge observed during interviews may be yet another factor influencing the large EI including EE gap. Inadequate competence makes it difficult for the individual to know what to look for, to assess potential importance in relation to product development, and to know what to forward inside the firm. Environmental training as well as systems for collecting and handling EI including EE may improve the firm's ability to close the gap. The results in Tables 1and 2 clearly demonstrate the potential for identifying, collecting, compiling, and exploiting EI including EE beneficially in product development by improved stakeholder collaboration.

Finally, most external stakeholders involved in the interviews were positively surprised and pleased to be approached, some even flattered. Since they have relations to the firm, they were all willing to contribute with EI including EE. The case study work itself created a positive impression of the firm for two main reasons; 1) the case firm cares enough about its stakeholders to ask for their opinion, and 2) the case firm contributes to society by participating in research projects.

6. Conclusion

The purpose of this research has not been to build new theory; rather the single case study of a Norwegian manufacturing firm and its stakeholders has provided an extensive overview of different types and sources of EI including EE available, and demonstrated the viability of the stakeholder approach for the identification, collection, and compilation of EI including EE relevant to product development.

A substantial gap between EI including EE availability, "what's out there", and what the firm knows of was identified through the interviews. The information gap can to a great extent be explained by the firm's current information generating activities: ad-hoc informative stakeholder participation with a limited number of stakeholders. The firm's willingness to engage in stakeholder collaboration was largely based on perceived stakeholder importance; thus customers, competitors, and suppliers were used to provide information on an ad-hoc basis, through activities like product benchmarking, sales and marketing meetings, and communication, logistics, and purchasing activities. Based on the results, we find support to say that increased stakeholder collaboration is likely to yield more relevant EI including EE.

The understanding of EI including EE usefulness within the firm was found to be affected by current business priorities and goals, internal competence on environmental issues, in addition to function and professional training. Cultural framing and filtering mechanisms were observed; some departments had access to relevant EI including EE but did not see the potential benefit of it in relation to product development, others did not actively seek EI including EE when in a position to do so.

Since product development relies heavily on information (Hicks et al., 2002), the competent use of EI including EE in product development have the potential to add value to products beyond functionality, quality, and cost, and as a result enhance firms' competitiveness. For practitioners, the results indicate where firms can look for EI including EE and what they can look for. For researchers, the gap between EI including EE availability and knowledge within the firm indicates a need for further studies on the information flows between firms and their stakeholders in a product development context, but also on information flows within the firm itself. A future research path we hope to explore through empirical work is how EI including as defined in this article can be successfully exploited in product development in manufacturing firms.

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References

Andersen, B., 1999. Business Process Improvement Toolbox. ASQ Press, Milwaukee.
Andersen, B., Fagerhaug, T., 2002. Performance Measurement Explained. Designing and Implementing Your State-of-the-Art System. ASQ Press, Milwaukee.

Baumann, H., Boons, F., Bragd, A., 2002. Mapping the green product development field: engineering, policy and business perspectives. Journal of Cleaner Production 10, 409–425.
Boks, C., Stevels, A., 2003. Theory and practice of environmental benchmarking in a major consumer electronics company. Benchmarking - An International Journal 10, 120–135.
Bos-Brouwers, H.E.J., 2009. Corporate sustainability and innovation in SMEs: evidence of themes and activities in practice. Business Strategy and the Environment.
Braganza, A., 2004. Rethinking the data-information-knowledge hierarchy: towards a case-based model. International Journal of Information Management 24, 346–347.
Byggeth, S., Hochschorner, E., 2006. Handling trade-offs in ecodesign tools for sustainable product development and procurement. Journal of Cleaner Production 14, 1420–1430.
Cramer, J., 2002. From financial to sustainable profit. Corporate Social Responsibility and Environmental Management 9, 99–106.
Cross, N., 2008. Engineering Design Methods - Strategies for Product Design, fourth ed. John Wiley & Sons Ltd., England.
Darnall, N., Jason, N., Handfield, R., 2008. Environmental management systems and green supply chain management: complements for sustainability? Business Strategy and the Environment 17, 30.
Delmas, M., Toffel, M.W., 2004. Stakeholders and environmental management practices: an institutional framework. Business Strategy and the Environment 13, 209–222.
Donaldson, T., Preston, L.E., 1995. The stakeholder theory of the corporation: concepts, evidence, and implications. The Academy of Management Review 20, 65–91.
Elkington, J., 1998. Cannibals with Forks - The Triple Bottum Line of 21st Century Business. New Society Publishers, Canada.
Erlandsson, J., Tillman, A.-M., 2009. Analysing influencing factors of corporate environmental information collection, management and communication. Journal of Cleaner Production 17, 800–810.
Foster, C., Green, K., 2000. Greening the innovation process. Business Strategy and the Environment 9, 287.
Freeman, R., 1984. Strategic Management: a Stakeholder Perspective. Prentice-Hall, Engelwood Cliffs, NJ.
González-Benito, J., González-Benito, Ó., 2008. A study of determinant factors of stakeholder environmental pressure perceived by industrial companies. Business Strategy and the Environment.
Henriques, I., Sadorsky, P., 1999. The relationship between environmental commitment and managerial perceptions of stakeholder importance. The Academy of Management Journal 42, 87–99.
Hicks, B.J., Culley, S.J., Allen, R.D., Mullineux, G., 2002. A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design. International Journal of Information Management 22, 263–280.
Hoffmann, E., 2007. Consumer integration in sustainable product development. Business Strategy and the Environment 16, 322.
Hubka, V., Andersen, M.M., Eder, W.E., 1988. Practical Studies in Systematic Design. Butterworth&Co, UK.
IPP, 2003. Commission of the European Communities. COM (2003) 302 final. Communication from the Commission to the Council and the European Parliament - Integrated product policy - Building on environmental life-cycle Thinking.
IPPC, 1996. Commission of the European Communities. Council Directive 96/61/EC of 24 September 1996 Concerning Integrated Pollution Prevention and Control.
Karlsson, C., 2009. Researching Operations Management. Taylor & Francis.
Karlsson, R., Luttropp, C., 2006. EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the papers in this special issue. Journal of Cleaner Production 14, 1291–1298.
Kong, N., Salzmann, O., Steger, U., Ionescu-Somers, A., 2002. Moving business/industry towards sustainable consumption: the role of NGOs. European Management Journal 20, 109–127.
Leire, C., Thidell, Å., 2005. Product-related environmental information to guide consumer purchases - a review and analysis of research on perceptions, understanding and use among nordic consumers. Journal of Cleaner Production 13, 1061–1070.
Lundgren, M., Catasus, B., 2000. The banks' impact on the natural environment - on the space between 'what is' and 'what if'. Business Strategy and the Environment 9, 186.
Maxwell, D., van der Vorst, R., 2003. Developing sustainable products and services. Journal of Cleaner Production 11, 883–895.
Nonaka, I., 1994. A dynamic theory of organizational knowledge creation. Organization Science 5, 14–37.
Oxley Green, A., Hunton-Clarke, L., 2003. A typology of stakeholder participation for company environmental decision-making. Business Strategy and the Environment 12, 292–299.
Peattie, K., 2001. Golden goose or wild goose? The hunt for the green consumer. Business Strategy and the Environment 10, 187.
Polonsky, M.J., Ottman, J.A., 1998. Exploratory examination of whether marketers include stakeholders in the green new product development process. Journal of Cleaner Production 6, 269–275.
Porter, M.E., van der Linde, C., 1995. Green and competitive: ending the stalemate. Haward Business Review 73.
REACH, 2006. Commission of the European Communities. Directive 2006/1907/EC of the European Parliament and of the Council of 18th December 2006 concerning the Registration, evaluation, Authorisation and restriction of chemicals (REACH), establishing a European chemicals Agency.
RoHS, 2002. Commission of the European Communities. Directive 2002/95/EC of the European Parliament and of the Council of 27 th January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.
Roy, M.-J., Thérin, F., 2008. Knowledge acquisition and environmental commitment in SMEs. Corporate Social Responsibility and Environmental Management 15, 249–259.
Waage, S.A., 2007. Re-considering product design: a practical "road-map" for integration of sustainability issues. Journal of Cleaner Production 15, 638–649.
Zins, C., 2007. Conceptual Approaches for defining data, information and knowledge. Journal of the American Society for Information Science and Technology 58, 479–493.

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Towards a framework for sustainability information in product development

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Towards a framework for sustainability information in product development

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Important, accessible and accurate sustainability information (SI) beyond product and process data is a prerequisite for making knowledge-based decisions in product development and for reducing the unsustainable impacts of products. This article introduces a definition of SI relevant to product development and synthesises existing literature from the period 2000–2010 with the purpose of identifying, collecting and compiling relevant SI into a framework. The aim has been to demonstrate the value of using more and other types of information in sustainable product development than is done through the current scope of existing tools and methodologies. The competent use and exploitation of SI in product development have the potential to lead to the development of more sustainable products and to enhance firms' competitiveness through adding value to products beyond functionality, quality and cost.

Keywords: sustainability; information; product development; stakeholder

1. Introduction

The tangible consequences in economic, environmental and social systems resulting from industrial activities and unsustainable consumption are more than ever forcing firms to improve their overall sustainability performance. Product development and product design have in this respect been the target of much interest from researchers, since up to 80% of the environmental and social cost factors of a product are determined in these early phases (Charter and Tischner 2001, Maxwell and van der Vorst 2003). It is at this stage that improvements to the sustainability attributes of a product can be made most effectively. Developing more sustainable products is a challenging journey to firms, as environmental and social impacts from a product may occur at all life cycle stages and involve a large number of stakeholders, most of them outside the firms' control.

Product development depends heavily on information to achieve its main tasks (Hicks *et al.* 2002). Hence, for knowledge-based decisions to be made in product development, seeking out relevant information about sustainability issues may be the best way for firms to improve their products. Such information does not just appear, it has to be '...collected, compiled and disseminated' (Erlandsson and Tillman 2009). Traditionally, the main focus on information in product development has been on environmental information concerning product and process data needed for life cycle assessment (LCA), various ecodesign tools, environmental certificates, etc. Less research explores other types of information relevant to product development, or information concerning the broader context of sustainability issues.

There is some research on sustainability disclosure covering transformation of information from a firm to its stakeholders (Moffat and Auer 2006, Brown *et al.* 2009). Others have focused on IT systems for environmental information management within a firm (Carlson *et al.* 2001, Frysinger 2001), systems that mainly focus on how to capture, store and retrieve environmental information, disregarding the actual information identification and collection. Yet, other researchers have focused more on the potential for knowledge acquisition through stakeholders (Roy and Thérin 2008, Bos-Brouwers 2010), but without identifying relevant information.

In a product development context, a review of ecodesign tools and methods concluded that relevant information may be found among different actors of a firm, which requires a broader network of actors than traditionally considered in product development and design (Baumann *et al.* 2002). Other researchers have reviewed external stakeholders such as universities, consultants, NGOs, end-users and regulators as senders of green information and signals relevant to the green innovation process (Foster and Green 2000). The most recent addition is a framework for corporate environmental information collection, management and communication (Erlandsson and Tillman 2009). This framework sorts out what corporate environmental information is, and examines stakeholders as influencing factors, but not in the context of product development.

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Based on the limited research available, we argue that there is a need to identify, collect and compile information beyond mere product and process data and environmental issues. For firms engaged in the development and manufacturing of new products, or in improving existing products, using such information to build knowledge on sustainability issues in product development may help these firms develop a broader vision on sustainable product development as well as provide useful additions to already existing practices in the field. Hence, the main purpose of this article is to explore what such sustainability information (SI) in relation to product development is, and what stakeholders are involved. The assumption behind the present work is that SI may be a key to increased knowledge in product development, which may further enhance firms' ability to develop and manufacture more sustainable products. Sustainability may be one way of adding value to products beyond functionality, cost and quality, and thus enhance firms' competitiveness.

In this article, the exploration of SI has been performed through the development of a SI framework, since a framework is an easy-to-understand way of compiling potentially relevant information. This framework renders further studies on SI possible. With more knowledge on SI in general, it may be possible to study which SI is most influential in relation to sustainable product development, how such information can be made more accessible to firms and which factors influence the importance and accessibility. The ultimate goal of such studies is to develop knowledge that may increase manufacturing firms' ability to develop sustainable and commercially viable products.

1.1 Terminology

SI in this article is defined as stakeholder information elements potentially capable of contributing to knowledge in product development, combining the environmental, social and economic dimensions of sustainability. SI explicitly includes information beyond internal product and process-related data, sustainability expectations from firm stakeholders towards the product itself or towards the firm (Aschehoug *et al.* 2011). The definition of SI is a synthesis of the triple bottom line (TBL) concept (Elkington 1998), stakeholder theory (Freeman 1984, Andersen and Fagerhaug 2002) and information and knowledge theory (Nonaka 1994, Hicks *et al.* 2002). This research is grounded on stakeholder theory as all firms have stakeholders. Moreover, the relationship between a firm and its stakeholders may be characterised by a mutual exchange process of money, goods, information and expectations (Andersen and Fagerhaug 2002). The present interest is on information and expectation flows on sustainability issues relevant to product development.

2. Method

The development of a framework was chosen, as this is a pragmatic approach to combining in a new way identified, collected and compiled SI from existing approaches, frameworks, strategies, methods and tools for improving sustainability performance of products and firms in a broad context. The present SI framework was developed based on the scientific literature from peer-reviewed articles from English language scientific journals from 2000 to 2010. The articles were identified through database search in *Science Direct* and *Wiley Online Library*. Derived from the above definition of SI, examples of keywords used in the literature search are presented in Table 1. Moreover, references in relevant articles were used as a second source for finding additional literature.

More than 280 articles were examined in the search for SI elements: 158 of these were found to address elements

Table 1. Keywords employed in the literature search.

Sustainability	Stakeholders	Information	Product development
Sustainability	Stakeholder(s)	Information	Product development
Sustainable	Multi-stakeholders	Knowledge	Product design
Environment(al)	Management		Ecodesign
Green	Manager(s)		
Ecology/ecological	Employee(s)		
Ethic(al)	Financial institution(s)		
Social	Supplier(s)		
Corporate social responsibility (CSR)	Banking/bank(s)		
	Insurance		
	Competitor(s)		
	Consumer(s)/customer(s)		
	NGO(s)		
	Academia/academic(s)/university		
	Industry association(s)/trade association(s)		
	Media/news/Internet		
	Government(s)/governmental/legislation		
	Community		

of SI. In addition, the use of stakeholder theory has supported the systematic collection of potentially relevant SI by providing a systematic approach to addressing 'anything influencing or influenced by the firm' (Freeman 1984, Donaldson and Preston 1995).

For information to be truly useful for firms, the SI also has to be important (to product development), accessible (easy to obtain) and accurate (represent a fact with some degree of precision and exactness) (Lee *et al.* 2002). Thus, SI was searched for in a wide context, using the following leading questions:

- What kind of SI is potentially important to product development?
- From which activities and from where (stakeholder groups) is the SI available?
- With what degree of accuracy can the information generally be described?

3. Introduction to relevant stakeholders

3.1 Government

SI from the European Commission's (EC) directives, legislation and regulations is provided from governmental agencies. The EC has passed several directives and regulations, mandatory for all European Union member countries and its associates. For this reason, most European countries have adopted and transposed the EC directives into national legislation (Angerer *et al.* 2008).

The many product-oriented environmental policies [waste from electric and electronic equipment (WEEE), end-of-life vehicle (ELV), energy-using products (EuP) and restriction of hazardous substances (RoHS)] demonstrate a shift towards more holistic approaches to managing the impacts from production–consumption systems (Tukker 2006). The extended producer responsibility (EPR) principle plays a similar role. The purpose is to promote life cycle environmental improvements, to reduce pollution as well as resource and energy use, by extending the responsibility of the producer to other parts of the life cycle, especially the product's end-of-life (EOL) phase (Honkasalo 2001, Rosen *et al.* 2002, Sanne 2002, Li and Geiser 2005, Gehin *et al.* 2008).

In addition to regulations, some countries' public agencies and other large institutions have developed specific guidelines for big volume purchases and guidelines for environmentally responsible public procurement (Li and Geiser 2005). The aim is to give preferences to products or services that are environmentally friendly, and to create a market for environmentally benign products (Li and Geiser 2005).

Linked to sustainable product development, every relevant requirement of the EC must be looked upon as mandatory in terms of product specifications and requirements, as firms' continued access to European markets depends on the product's ability to meet EC requirements (Rock *et al.* 2006).

3.2 Non-governmental organisations (NGOs)

NGOs are legally constituted organisations that operate independently from any government (Kong *et al.* 2002). NGOs are traditionally involved in product development, green labelling, standardisation schemes and green purchasing (Jasch 2000, Kong *et al.* 2002, de Boer 2003, Erlandsson and Tillman 2009). NGOs may be involved in developing sustainable products together with firms, and have power to create market demands for sustainable products (Kong *et al.* 2002).

NGOs can also play the role of consumer organisations and provide information on test results on, e.g. household appliances (Kong *et al.* 2002), in which a firm's products' environmental performances in relation to those of competitors' products are displayed. NGOs may also collect information on environmental claims regarding different products or firms (Kong *et al.* 2002). Negative publicity campaigns from NGOs (Buysse and Verbeke 2003) may be another source of SI relevant to product development.

NGOs are often the holders of eco-labelling and standardisation schemes. The labels refer to the qualities of products or production processes and assure the buyers of the authenticity of the product or service provided by a firm. These labels may be divided into generic labels, sector-specific labels or regional labels (de Boer 2003). Information on requirements for sustainability labelling and standardisation may be regarded as mandatory input into product specifications and requirements for firms aiming for such.

3.3 Media

Media channels [TV, radio, newspapers, newsgroups, mailing lists and Internet (Facebook, Blogs and Twitter)] have the power to influence and shape customers' behaviour. Media may act as information mediators for other stakeholders, or present new information. The way a product or firm is portrayed in media may directly influence sales numbers. A documentary on harmful substances that may endanger customers' health might affect customers' perceptions of all products containing these substances and their producers. Media channels such as Internet, including social network services, make information on products and firms more accessible than ever, giving customers new power (Kong *et al.* 2002). Damaging information and displays may force firms to change their products or activities, thus also impacting product development.

3.4 Shareholders and investors

It is common belief that environmental protection issues are costly and conflict with economic shareholder values

(Prakash 2002). Opposite views, the win–win paradigm argues that high focus on environmental issues is beneficial to such shareholder values (Halme and Niskanen 2001). A recent study claims that larger environmental improvements following environmental investments are associated with expectations of higher financial gains (Plaza-Ubeda *et al.* 2009). A growing number of empirical studies also report on a positive relationship between corporate social performance and financial performance (Callan and Thomas 2009, Alniacik *et al.* 2011) meaning that firms do not need to view sustainability and profitability as conflicting goals.

As shareholders and investors are increasingly concerned with corporate pollution and the risk of costly sanctions (Halme and Niskanen 2001), this concern may also be expanded to include products, as the EPR principle is becoming increasingly important (Li and Geiser 2005). We expect shareholders to be reluctant to invest in products resulting in harmful social conditions during use, or in irreversible environmental damage after its EOL. Knowing shareholders' attitudes and values in these matters is consequently important and such information should be considered when setting product development objectives.

3.5 Academia and industry associations

Research and cooperation between academia (universities and research institutions) and firms may provide opportunities for mutual learning, knowledge and practice exchange (Roy and Thérin 2008, Erlandsson and Tillman 2009). Research institutions and industry associations are frequently involved in the development of or revisions of sustainability standards (Erlandsson and Tillman 2009) or legislation and may consequently act as 'knowledge brokers' for firms. Especially, for smaller firms, cooperation with knowledge institutions may be important in innovation projects (Bos-Brouwers 2010).

3.6 Financial institutions

Financial institutions are increasingly engaging in environmental activities. Their environmental influence is typically physical, financial or immaterial (Lundgren and Catasus 2000). The *physical flow* refers to the banks' own environmental stewardship and includes issues such as recycling paper, demanding ISO 14001 certified suppliers, introducing low energy lighting/heating/cooling and responsible waste management. The *financial flows* are concerned with the core business of banks. Environmental and ethical checklists to protect the banks' own profitability is another way of influencing firms' actions (Lundgren and Catasus 2000). The bank can demand a higher risk premium for poor environmental performers, withdraw capital, refuse to extend new loans to such firms (Buysse and Verbeke 2003) or favour firms by offering low-interest loans based on environmental performance (Lundgren and Catasus 2000, Jayne and Skerratt 2003). Another way banks exert influence is through funds specially developed for firms aiming at environmental improvements. The EU has, for instance, a fund programme called *Growth and the Environment*, through which it sponsors initiatives by sharing the potential loss of a loan (Lundgren and Catasus 2000). *Immaterial flows* are concerned with the indirect impact information, knowledge, culture and policies have on the environment (Lundgren and Catasus 2000).

In a product development context, knowing banks' sustainability values might make firms bargain for more favourable interest rates based on product development portfolios. Firms may also be willing to change product development strategies to qualify for special risk funds.

3.7 Competitors

Engaging in stakeholder partnerships with competitors to gain information relevant to product development is for most firms not an option for confidentiality reasons. Benchmarking may, however, be an option. Benchmarking is 'the process of continuously measuring and comparing one's business process against comparable process in leading organizations to obtain information that will help the organization identify and implement improvement' (Andersen 1999). Competitive benchmarking allows for comparison with a firm's closets direct competitors. Performance benchmarking makes it possible to compare key figures on, for instance, a product's sustainability performance.

Environmental benchmarking is a method for improving products (Boks and Stevels 2003). It creates a link between environmental awareness and product design, as the benchmark gives information on current product environmental performance, and provides a platform for discussions on further improvements. SI derived from product performance benchmarking is typically product and process oriented: durability, problematic materials used, volume, weight, etc. (Boks and Stevels 2003).

3.8 Suppliers

Unsustainable impacts upstream or downstream a supply chain may occur in other parts of the product chain than at the firm's own production sites. In order to make sound decisions in product development, information about suppliers is needed outside the current scope of quality, economy and functionality issues. Well-known firms such as Nike have learned the hard way that public accusations of child labour and environmentally harmful practices lead to loss of reputation, sales and customers (Young and Kielkiewicz-Young 2001).

Sustainable supply chain management (SSCM) may be one way of generating the necessary information as input for product development. SSCM 'is the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental and social, into account which are derived from customer and stakeholder requirements' (Seuring and Müller 2008). Reported advantages from engaging in SSCM are increased sales, more satisfied customers, smoother supply systems and reduced costs (Handfield *et al.* 2005, Sharfman *et al.* 2009). Supplier involvement is also recommended as suppliers have specialised product and process capabilities. Utilising such information in product development may reduce time to market, improve product quality and reduce costs (Johansson and Magnusson 2006).

Dow Chemicals for instance cooperated with its transportation suppliers to design an innovative and safer rail car. In the automotive industry, similar partnerships with paint and chemical suppliers are common in order to develop more environmentally benign products that car makers cannot otherwise develop (Darnall *et al.* 2008). Other researchers suggest that firms must integrate environmental management strategies into all supply chain stages, including product design, procurement, manufacturing, packaging and logistics in order to be successful (Handfield *et al.* 1997).

3.9 Customers (value chain and end-users)

A holistic approach to sustainable product development allows for preferences, views and behaviours of customers (Krantz 2010). Considering sustainable consumption in relation to product development provides the product designer with opportunities for developing creative concepts for immaterial culture and for proposing new ways of organising daily life (Marchand and Walker 2008).

Information on customers' environmental awareness, acceptance and behaviour change may be very relevant to product development (Gilg *et al.* 2005). By making the sustainable features of products more visible and apparent through product design, one can enable customers to choose sustainable products and services and to engage in sustainable lifestyles. Providing ecological and socially acceptable product alternatives may be a way for designers to influence and encourage customers already interested in directing their habits towards more sustainable consumption (Marchand and Walker 2008). Monitoring product usage, for instance, may provide valuable information on customers' decisions on preventive maintenance and EOL decisions that is crucial to developing products with an ecological and environmental EOL process as in design for remanufacturing (Sundin and Bras 2005).

Likewise, understanding sustainability attitudes among potential customers is important to determining appropriate marketing strategies that may influence commercial success and continuation of sustainable product development. A complicating factor is, however, customers' tendency to overestimate their own willingness to purchase eco-labelled and environmentally friendly products (Peattie 2001).

Within the area of marketing, researchers have focused their work on why green marketing fails and on the failing willingness among consumers to pay for green products (Meyer 2001, Peattie 2001, Prakash 2002, Chamorro *et al.* 2009, Thun and Muller 2010). The most important factor identified in the literature is the cost–benefit difference. The often forgotten issues related to the cost of the products include factors such as 'search cost' (green products are often less available), 'information costs' (you have to be informed to consider alternatives), 'product cost' (selling price), 'cost of usage' (unlearning old behaviour or learning new behaviour) and 'cost of disposal' (special requirements for disposing of the product) (Meyer 2001, Peattie 2001). Together, all these costs may be perceived to override the benefit side. Consequently, information on customer costs and benefits should be included in product development.

3.10 Management and employees

In product development, a key issue is how internal stakeholders respond to external stakeholders' concerns and expectations, as internal stakeholders' responses influence actions and decision making in product development. Stakeholder pressure is exerted and received on various levels in a firm. Consequently, the way internal stakeholders react is dependent on the recipients' organisational belonging (Delmas and Toffel 2004). Engineers may perceive environmental pressures differently from legal departments. Legal departments are likely to interpret pressures in terms of risks, liability and lawsuits. Engineers are likely to be more concerned with direct operating consequences. Likewise, the source of the environmental information and the managers' perception of the source may influence how managers adopt new environmental practices (Henriques and Sadorsky 1999, Delmas and Toffel 2004). Information from shareholders is likely to be viewed as very important by managers, while information from NGOs may be regarded as being less important to product development.

Managers' personal values, beliefs, commitment and knowledge on sustainability also influence how they understand and assess the importance of stakeholder concerns and requirements (González-Benito and González-Benito 2006, Plaza-Ubeda *et al.* 2009). Although a manager with great knowledge and commitment to environmental issues is perceptive and responds positively to environmental expectations, also in a product development context, a manager with less commitment

to environmental issues is more likely to overlook or disregard such expectations.

Employees are also affected directly and indirectly by a firm's sustainable values and actions. Managerial attitudes and positions as motivators play an important role in environmental pro-activity (González-Benito and González-Benito 2006). Studies have also shown that conventional business aspects such as customisation, organisation and commitment are all important success factors for implementation (Boks 2006). Consequently, firm actions and commitments as to sustainability issues influence product development directly or indirectly.

In-house information on sustainability issues is also important to consider. Even if hazardous substances are eliminated in product development, workers may be exposed to other safety hazards, or may not have freedom of association. Products safe for customers are still not sustainable if workers' conditions are compromised during manufacturing, or if manufacturing results in adverse effects on the local community.

4. The sustainability information framework

Identified, collected, and compiled, Table 2 presents the SI framework by stakeholder group, which is identified, collected and compiled. The SI framework presents key information elements potentially relevant to sustainable product development in the manufacturing industry, independent of firm size. The SI elements are organised based on their most prominent product life cycle phase, as information on sustainability impacts across all stages is equally important to sustainable product development. The life cycle stages used to organise the information are materials, manufacturing, transport, use and disposal (Hauschild *et al.* 2005, McAloone and Bey 2009). Many of the information elements identified were overlapping, or they described the same information element with other words. In such cases, the information elements were reformulated and merged together. In order to develop an SI framework up to date with current developments and industrial practice, SI elements were reformulated where appropriate to include all TBL elements, not only the environmental domain as frequently described in the literature.

5. Discussion

Developing more sustainable products is considered a journey rather than a destination. This is challenging to firms as environmental and social impacts from products may occur at all life cycle stages and involve a large number of stakeholders. Efforts to guide firms on this journey have been made by reviewing scientific literature and identifying SI that may contribute to knowledge in product development.

Product development may be defined as 'the sequence of steps or activities which an enterprise employs to conceive, design and commercialize a product' and is often described as having six steps: planning, concept development, system level design, detailed design, testing and refinement and finally production and ramp-up (Ulrich and Eppinger 2008). Given that up to 80% of the environmental and social cost factors of a product are determined in the early development phases (Charter and Tischner 2001, Maxwell and van der Vorst 2003), it is argued that SI will be most efficient in creating knowledge at these stages. Court (1995) describes knowledge as the ability of the individuals to understand information, including how they handle, apply and use it in a given situation.

Although not envisioned as a tool itself, the information in the framework may be used for continuous sustainability improvements on existing products. SI may be used in the *planning phase* in developing detailed product requirements and specifications, in developing proposals and a broad range of product scheme solutions in the *conceptual phase*, and in choosing between different product schemes in *system level design*, as well as in supporting decision making in the later phases of product development. Information on current or future regulations regarding sustainability issues or requirements for sustainability labelling are the examples of SI relevant to requirements in the analysis phase.

Instead of using SI to create knowledge for developing requirements or other foundations for decision making in product development, another approach is to view SI as a possibility in building knowledge about future scenarios. Sustainability knowledge on future scenarios and trends may inspire firms to propose entirely new meanings to products. Verganti (2009) has argued that radical innovations of product meanings are rarely pulled by users, but are instead proposed by firms through design-driven innovations through manufacturers' knowledge on future socio-cultural evolutions. Consequently, firms' interactions with various stakeholders to collect SI may generate such knowledge, which again may inspire new product meanings based on sustainability. In such cases, the potential impacts of firms' SI use to society at large are significant.

Appreciating that product development processes differ between industries, firms, and also between different products, the authors believe that the SI framework may be suitably customised in line with current demands in firms or industries. Such customisation may be based on information quality criteria that depend on the context, on the problem at hand, as well as on the information customer (i.e. information user) (Salaün and Flores 2001, Hicks *et al.* 2002, Lee *et al.* 2002). As product developers are main SI customers, any customisation should reflect

Table 2. A framework for SI elements for product development.

Stakeholder group	Life cycle stage	Description of SI element ('information on ....')	Accessibility
Government	All	Registration, evaluation and authorisation of chemicals (REACh)	REACh EC Directive
	All	EcoDesign Directive for Energy Using Products (EuP)	EuP EC Directive
	All	Restriction of the Use of Certain Hazardous Substances in Electrical Equipment (RoHS)	RoHS EC Directive
	All	European Commission Green Paper on Integrated Product Policy (IPP)	IPP EC Green paper
	All	Purchasing guidelines and requirements for social and environmental responsible public procurement	Governmental and institutional purchase guidelines. Invitation to submit tenders, etc.
	All	Export/import countries' sustainability regulations	National governments
	All	Pre-regulations (new regulations) concerning sustainability issues	National governments, EC
	All	Governmental campaigns targeted at raising sustainable awareness and changing consumers' behaviour	
	Manufacturing	National guidelines and priorities within integrated pollution prevention and control	National governments
	Transport	Packaging and packaging waste	Packaging Waste EC Directive
	Disposal	End-of-Life Vehicle (ELV)	ELV EC Directive
	Disposal	The Waste from Electric and Electronic Equipment (WEEE)	WEEE EC Directive
	Disposal	National extended producer responsibilities (EPR) (including take-back or EOL handling obligations for producer)	National EPR requirements
NGOs	All	Campaigns targeted at raising sustainable awareness and changing consumer behaviour and firms' procurements policies (positive information)	TV, newspapers, magazines and Internet observations and monitoring
	All	Campaigns targeted at raising sustainable awareness and changing consumer behaviour and firms' procurements policies (positive information)	
	All	Partnerships and coalitions with firms regarding sustainable problem solving, product development, to ensure transparency or promote community participation	
	All	Sustainable performance test results and ranking lists	
	All	Requirements for sustainability labelling or sustainability certificates managed by NGOs	Standards
	All	Buying shares in firms to vote, launch campaigns or lobby other shareholders	Stock news
Media	All	Documentaries and campaigns targeted at specific products, substances, firms or industries	TV, newspapers, magazines and Internet observations and monitoring (Facebook groups, discussion forums, product pages and blogs)
	All	Interests, values, preferences and dislikes related to a product or firm	
	All	Social and environmental disclosures on Internet on products, substances, firms or industries	

Table 2 – *continued*

Stakeholder group	Life cycle stage	Description of SI element ('information on ....')	Accessibility
Shareholders investors	All	Attitudes and values on sustainability issues	Shareholder meetings: voting or discussions
	All	Decisions to invest, not to invest or divest in firms due to sustainability concerns	
	All	Sustainability investment criteria for funds	
Scientific community/ academia	All	Priority settings for new sustainability-related research areas and calls	Stakeholder collaboration and participation in networks
	All	Work and cooperation with standardisation organisations	
	All	Sustainability issues through knowledge exchange, practice transfer (workshops and students) and research	
	All	Willingness to share the costs of innovation processes through partnerships with firms	
Industry associations	All	Current or pre-regulations concerning sustainability issues	Stakeholder collaboration and participation in networks
	All	Transparency in decision making within the industry sector	
	Manufacturing	Sustainable technologies and other relevant sustainable issues	
Financial institutions	All	Sustainability policy declarations and sustainable stewardship	Stakeholder collaboration, internal staff magazines, banking magazines, advertisements
	All	Sustainability 'edged' financial products	
	All	Checklists and criteria regarding sustainability risks (positive or negative criteria)	
	All	Philanthropy activities including engagement in community and sponsoring of organisations or events	
	All	Commitment not to accept money laundering and illegal business	
	All	Commitment to increase transparency, i.e. to provide their stakeholders with detailed information regarding where the money comes from and for what purposes it is lent out	
Competitors	All	Communication and marketing materials on sustainability issues	Sustainability benchmarking
	All	Corporate sustainability policies and management systems	
	All	Sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customers or markets (e.g. AA1000, GRI)	
	All	Education and training programs for employees (sustainability related and other programs)	
	All	Labour practices (SA 8000, fair labour code of conduct and ILO's Decent Work standard)	
	All	Adherence to legislation or voluntary sustainability labelling or sustainability certificates/standards	

Table 2 – *continued*

Stakeholder group	Life cycle stage	Description of SI element ('information on ....')	Accessibility
	Materials	Use and volume of hazardous substances, reusable or recyclable materials or unsustainable materials in the product or in packaging	
	Materials	Sustainability-focused supplier programmes, including audits	
	Materials, use	Fasteners, connections, modularity, standard parts, weight and volume	
	Manufacturing	Use of sustainable production technology	
	Transport	Frameworks for reusable or recyclable packaging/containers for transportation of goods	
	Transport	Location (distance) and means of transportation of products (water, rail, road and air)	
	Use	Energy consumption during use of product, including usage scenarios	
	Use	Waste, emissions, noise and vibrations generated during use of product	
	Use	Cost or purchase price for product	
	Use, disposal	Lifetime, durability, reliability, upgrade options, maintenance requirements and EOL scenarios	
Suppliers	All	Corporate sustainability policies and management systems	Sustainable supply chain management (SSCM)
	All	Supplier's general sustainability orientation and compliance orientation (more than minimum)	
	All	Sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customers or markets (e.g. AA1000 and GRI)	
	All	Adherence to legislation or voluntary sustainability labelling or sustainability certificates/standards	
	All	Contribution to internal population shifts (e.g. from rural to urban areas)	
	All	Philanthropy activities including engagement in community and sponsoring of organisations or events	
	All	Adherence to the UN human rights declaration	
	All	Direct and indirect employment in developing countries	
	All	Education and training programmes for employees (sustainability related and other programmes)	
	All	Labour practices (SA 8000, fair labour code of conduct and ILO's Decent Work standard)	
	All	Commitment to advertising norms, i.e. responsible marketing	
	All	Support of oppressive regimes	
	All	Honesty, trust, respect and fairness in business relations	
	All	Service, price, quality, cost and delivery	
	All	Innovation abilities and product development activities	
	All	Financial situation and stability	
	All	Internal employee satisfaction and participation in decision making	

Table 2 – *continued*

Stakeholder group	Life cycle stage	Description of SI element ('information on ....')	Accessibility
	Materials, manufacturing	Local impacts on natural resources, land and biodiversity at suppliers' production facilities	
	Materials	Use and volume of hazardous substances, reusable or recyclable materials, or unsustainable materials in the product or in packaging	
	Materials	Energy use (non-efficient, non-renewable and non-sustainable sources of energy) or commitment to energy-saving projects	
	Materials	Volume and use of materials, use of reusable and recyclable materials	
	Materials	Supplier's supplier selection programmes and purchasing policy	
	Transport	Frameworks for reusable or recyclable packaging/containers for transportation of goods	
	Transport	Location (distance) and means of transportation of products (water, rail, road, air)	
Customers (value chain and end-customers)	All	Perception of the firm's sustainability image (reputation)	Stakeholder collaboration, customer research
	All	Preferences for sustainability-labelled products or sustainability certificates	
	All	Sustainability perception of the product (e.g. if the product is considered better/worse than similar products on the market)	
	All	Sustainable performance requirements towards delivered product or service	
	All	Preference for sustainable products from sustainable firms	
	All	Fashions and trends within the product segment, trend sensitivity and the wish to have up-to-date products	
	All	Behaviour in a social–cultural market context, what influences the purchase decision	
	All	The product's contribution to internal population shifts (e.g. from rural to urban areas)	
	All	Sustainability awareness	
	All	View on non-price-based costs (gathering information about the product, effort to make the purchase, using or disposing of the product a certain way)	
	Use	Energy consumption during use of product, including usage scenarios	
	Use	Preferences for services instead of physical products. Social barriers towards shared use of products or open-mindedness towards renting and shared use	
	Use	Use of current products on market or similar products if product does not exist, with respect to sustainability aspects (lifetime, durability, reliability, upgrade options, maintenance requirements and EOL scenarios)	
	Use	Perceived personal factors and benefits from the product (satisfaction), perceived product meaning	

Table 2 – *continued*

Stakeholder group	Life cycle stage	Description of SI element ('information on ....')	Accessibility
	Use	Ability to be engaged in the activity of 'doing' things with the product, the preference for intelligent products	
	Use	Lock-ins and habits of unsustainable practices	
Internal stakeholders (management, employees)	All	Stakeholder sustainable performance requirements and information received at different functions and levels in the firms	Stakeholder collaboration and partnerships
	All	Commitment to involve users and other stakeholders in product development to enhance organisational and individual learning	
	All	Stakeholders' partnerships and dialogs and involvement in decision making, communication with stakeholder groups (e.g. AA1000 and GRI)	
	All	Commitment and adherence to corporate sustainability policies and management systems	Internal communication and information flows
	All	Education and training programmes for employees (sustainability related and other programmes)	
	All	Internal employee satisfaction and participation in decision making	
	All	Labour practices (SA 8000, fair labour code of conduct and ILO's Decent Work standard)	
	All	Freedom of speech and open information in firm	
	All	Firm's impact and involvement in local and global community through production, usage and EOL scenarios	
	All	Commitment to transparency in firm decision making	
	All	Commitment to avoid bribery and corruption, as well as to secure transparency regarding political contributions	
	All	Philanthropy activities including engagement in community and sponsoring of organisations or events	
	All	Commitment to advertising norms, i.e. responsible marketing (e.g. greenwashing, not provide damaging offers)	
	All	Commitment to honesty, trust, respect and fairness in business relations (fair pricing and competition)	
	All	CSR or green activities giving average positive profit margins (not above or below average)	
	All	Firm's contribution to internal population shifts from rural to urban areas	
	All	Adherence to sustainability labelling (e.g. EU flower, EU energy label, Nordic Swan, German Blue Angels, Forest Stewardship Council, Marine Stewardship Council, Fair Trade, Energy Star, etc.)	
	All	Adherence to sustainability standards (e.g. ISO 14000 series)	
	All	Involvement and sharing of product environmental responsibility with suppliers	
	All	Contribution to internal population shifts (e.g. from rural to urban areas)	
	All	Adherence to the UN human rights declaration	
	All	Direct and indirect employment in developing countries	

Table 2 – *continued*

Stakeholder group	Life cycle stage	Description of SI element ('information on ....')	Accessibility
	All	Support of oppressive regimes	
	Materials	Commitment to sustainable supply chain practices	
	Materials, manufacturing	Use and volume of hazardous substances, reusable or recyclable materials or unsustainable materials in the product or in packaging	
	Manufacturing	Commitment to use effective environmental accounting systems and management tools with performance indicators (e.g. TBL accounting, LCA, EPD, GRI)	
	Manufacturing	Impacts on local natural resources, land and biodiversity at production facilities	
	Manufacturing	Energy use (non-efficient, non-renewable and non-sustainable sources of energy), or commitment to energy-saving projects	
	Manufacturing	Firm discharge permits and permits applications	
	Manufacturing	Investments in sustainable technologies	
	Manufacturing	Excessive generation of waste from manufacturing processes, including scrap products	
	Transportation	Frameworks for reusable or recyclable packaging/containers for transportation of goods	
	Transportation	Location (distance) and means of transportation of products (water, rail, road and air)	
	Use	Commitment to include service policies that are provided to the customer during the use phase of products (to improve eco-efficiency and prolonged life of product), and to provide product update policies to customers	
	Disposal	Motivational activities towards customers to promote recovery of products and components for reuse, recycling or treatment/disposal, and to keep records of and track where the firm's products are (EOL instructions)	

Note: EOL, end-of-life; ILO, International Labour Organization; AA1000, accountability standard; GRI, global reporting initiative; SA 8000, social accountability standard; TBL, triple bottom line; LCA, life cycle assessment; EPD, environmental product declaration.

product developers' own views of SI importance to products' sustainability performance.

6. Conclusion

Product development has been the target of growing attention as a means of improving the sustainability performance of products. Although, to some extent, firms have succeeded in improving their products by applying tools for ecodesign and the like, taking sustainable product development to the next level may require a broader perspective than that of current industrial practice. Making use of more and other types of information to build knowledge on sustainability in product development may be an additional way for firms to improve their products and increase firm competitiveness under the assumption that increasing sustainability may be a way of adding value to products beyond traditional aspects of functionality, cost and quality.

Grounded in stakeholder theory, an SI framework has been developed based on extant scientific literature. The framework presents SI that is identified, collected and compiled across life cycle stages for the most relevant stakeholder groups. Compared to existing approaches, the SI framework represents an expansion of existing research: first, the focus is shifted from a supply chain or value chain perspective, in which only a limited number of stakeholders are considered, towards a holistic stakeholder approach which includes all firm stakeholders. Second, the framework incorporates information in a TBL context. As reviewed in the introduction, existing work so far is mainly concerned with environmental information. Third, the attention extends beyond the traditional product and process data boundaries, which opens up for the simultaneous considerations of more information elements in product development than before. Fourth, SI specifically targeted product development has been identified and compiled. The combination of the elements as presented here has to the authors' knowledge not previously been described in the literature.

The SI framework renders further studies on SI possible. With more knowledge on SI in general, researchers may study which SI is most important in relation to product development and how this information can be made more accessible to firms. It is expected that importance and accessibility of such information are dependent on industry sector, or even are firm specific. The ultimate goal of such studies is to develop knowledge that may increase manufacturing firms' ability to develop sustainable and commercially viable products.

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References

Alniacik, U., Alniacik, E., and Genc, N., 2011. How corporate social responsibility information influences stakeholders' intentions. *Corporate Social Responsibility and Environmental Management*, 18 (4), 234–245.

Andersen, B., 1999. *Business process improvement toolbox*. Milwaukee, WI: ASQ Press.

Andersen, B., and Fagerhaug, T., 2002. *Performance measurement explained. Designing and implementing your state-of-the-art system*. Milwaukee, WI: ASQ Press.

Angerer, G., Nordbeck, R., and Sartorius, C., 2008. Impacts on industry of Europe's emerging chemicals policy REACh. *Journal of Environmental Management*, 86 (4), 636–647.

Aschehoug, S., Boks C., and Støren S., 2011. Environmental information from stakeholders supporting product development. *Journal of Cleaner Production*, 222 (1), 1–9.

Baumann, H., Boons, F., and Bragd, A., 2002. Mapping the green product development field: engineering, policy and business perspectives. *Journal of Cleaner Production*, 10 (5), 409–425.

Boks, C., 2006. The soft side of ecodesign. *Journal of Cleaner Production*, 14 (15–16), 1346–1356.

Boks, C., and Stevels, A., 2003. Theory and practice of environmental benchmarking in a major consumer electronics company. *Benchmarking – An International Journal*, 10 (2), 120–135.

Bos-Brouwers, H.E.J., 2010. Corporate sustainability and innovation in SMEs: evidence of themes and activities in practice. *Business Strategy and the Environment*, 19 (7), 417–435.

Brown, H.S., de Jong, M., and Levy, D.L., 2009. Building institutions based on information disclosure: lessons from GRI's sustainability reporting. *Journal of Cleaner Production*, 17 (6), 571–580.

Buysse, K., and Verbeke, A., 2003. Proactive environmental strategies: a stakeholder management perspective. *Strategic Management Journal*, 24 (5), 453–470.

Callan, S.J., and Thomas, J.M., 2009. Corporate financial performance and corporate social performance: an update and reinvestigation. *Corporate Social Responsibility and Environmental Management*, 16 (2), 61–78.

Carlson, R., *et al.*, 2001. System for integrated business environmental information management. *Advances in Environmental Research*, 5 (4), 369–375.

Chamorro, A., Rubio, S., and Miranda, F., 2009. Characteristics of research on green marketing. *Business Strategy and the Environment*, 18 (4), 223.

Charter, M., and Tischner, U., 2001. *Sustainable solutions: developing products and services for the future*. Sheffield, UK: Greenleaf Publishing.

Court, A.W., 1995. Modelling and classification of information for engineering and design. Thesis (PhD). University of Bath, UK.

Darnall, N., Jason, N., and Handfield, R., 2008. Environmental management systems and green supply chain management: complements for sustainability? *Business Strategy and the Environment*, 17 (1), 30.

de Boer, Joop, 2003. Sustainability labelling schemes: the logic of their claims and their functions for stakeholders. *Business Strategy and the Environment*, 12 (4), 254–264.

Delmas, M., and Toffel, M.W., 2004. Stakeholders and environmental management practices: an institutional framework. *Business Strategy and the Environment*, 13 (4), 209–222.

Donaldson, T., and Preston, L.E., 1995. The stakeholder theory of the corporation: concepts, evidence, and implications. *The Academy of Management Review*, 20 (1), 65–91.

Elkington, J., 1998. *Cannibals with forks – the triple bottom line of 21st century business*. Oxford, UK: Capstone Publishing.

Erlandsson, J., and Tillman, A.M., 2009. Analysing influencing factors of corporate environmental information collection, management and communication. *Journal of Cleaner Production*, 17 (9), 800–810.

Foster, C., and Green, K., 2000. Greening the innovation process. *Business Strategy and the Environment*, 9 (5), 287.

Freeman, R.E., 1984. *Strategic Management: a stakeholder perspective*. Boston, MA: Pitman Publishing.

Frysinger, S.P., 2001. An integrated environmental information system (IEIS) for corporate environmental management. *Advances in Environmental Research*, 5 (4), 361–367.

Gehin, A., Zwolinski, P., and Brissaud, D., 2008. A tool to implement sustainable end-of-life strategies in the product development phase. *Journal of Cleaner Production*, 16 (5), 566–576.

Gilg, A., Barr, S., and Ford, N., 2005. Green consumption or sustainable lifestyles? Identifying the sustainable consumer. *Futures*, 37 (6), 481–504.

González-Benito, J., and González-Benito, Ó., 2006. A review of determinant factors of environmental proactivity. *Business Strategy and the Environment*, 15 (2), 87–102.

Halme, M., and Niskanen, J., 2001. Does corporate environmental protection increase or decrease shareholder value? The case of environmental investments. *Business Strategy and the Environment*, 10 (4), 200.

Handfield, R.B., *et al.*, 1997. 'Green' value chain practices in the furniture industry. *Journal of Operations Management*, 15 (4), 293–315.

Handfield, R., Sroufe, R., and Walton, S., 2005. Integrating environmental management and supply chain strategies. *Business Strategy and the Environment*, 14 (1), 1.

Hauschild, M., Jeswiet, J., and Alting, L., 2005. From life cycle assessment to sustainable production: status and perspectives. *CIRP Annals – Manufacturing Technology*, 54 (2), 1–21.

Henriques, I., and Sadorsky, P., 1999. The relationship between environmental commitment and managerial perceptions of stakeholder importance. *The Academy of Management Journal*, 42 (1), 87–99.

Hicks, B.J., *et al.*, 2002. A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design. *International Journal of Information Management*, 22 (4), 263–280.

Honkasalo, A., 2001. Eco-efficiency and integrated product policy: lessons from Finland. *Corporate Environmental Strategy*, 8 (2), 109–117.

Jasch, C., 2000. Environmental performance evaluation and indicators. *Journal of Cleaner Production*, 8 (1), 79–88.

Jayne, M.R., and Skerratt, G., 2003. Socially responsible investment in the UK—criteria that are used to evaluate suitability. *Corporate Social Responsibility and Environmental Management*, 10 (1), 1–11.

Johansson, G., and Magnusson, T., 2006. Organising for environmental considerations in complex product development projects: implications from introducing a "Green" subproject. *Journal of Cleaner Production*, 14 (15–16), 1368–1376.

Kong, N., *et al.*, 2002. Moving business/industry towards sustainable consumption: the role of NGOs. *European Management Journal*, 20 (2), 109–127.

Krantz, R., 2010. A new vision of sustainable consumption. *Journal of Industrial Ecology*, 14 (1), 7–9.

Lee, Y.W., *et al.*, 2002. AIMQ: a methodology for information quality assessment. *Information & Management*, 40 (2), 133–146.

Li, L., and Geiser, K., 2005. Environmentally responsible public procurement (ERPP) and its implications for integrated product policy (IPP). *Journal of Cleaner Production*, 13 (7), 705–715.

Lundgren, M., and Catasus, B., 2000. The banks' impact on the natural environment – on the space between 'what is' and 'what if'. *Business Strategy and the Environment*, 9 (3), 186.

Marchand, A., and Walker, S., 2008. Product development and responsible consumption: designing alternatives for sustainable lifestyles. *Journal of Cleaner Production*, 16 (11), 1163–1169.

Maxwell, D., and van der Vorst, R., 2003. Developing sustainable products and services. *Journal of Cleaner Production*, 11 (8), 883–895.

McAloone, T., and Bey, N., 2009. Environmental improvement through product development: A guide. *Danish Environmental Protection Agency*, Copenhagen, Denmark.

Meyer, A., 2001. What's in it for the customers? Successfully marketing green clothes. *Business Strategy and the Environment*, 10 (5), 317.

Moffat, A., and Auer, A., 2006. Corporate Environmental Innovation (CEI): a government initiative to support corporate sustainability leadership. *Journal of Cleaner Production*, 14 (6–7), 589–600.

Nonaka, I., 1994. Dynamic theory of organizational knowledge creation. *Organization Science*, 5, 14–37.

Peattie, K., 2001. Golden goose or wild goose? The hunt for the green consumer. *Business Strategy and the Environment*, 10 (4), 187.

Plaza-Ubeda, J.A., *et al.*, 2009. The 'win-win' paradigm and stakeholder integration. *Business Strategy and the Environment*, 18 (8), 487.

Prakash, A.A., 2002. Green marketing, public policy and managerial strategies. *Business Strategy and the Environment*, 11 (5), 285.

Rock, M.T., Lim, P.L., and Angel, D.P., 2006. Impact of firm-based environmental standards on subsidiaries and their suppliers: evidence from Motorola-Penang. *Journal of Industrial Ecology*, 10 (1–2), 257–278.

Rosen, C.M., Beckman, S.L., and Bercovitz, J., 2002. The role of voluntary industry standards in environmental supply-chain management. *Journal of Industrial Ecology*, 6 (3–4), 103–123.

Roy, M.-J., and Thérin, F., 2008. Knowledge acquisition and environmental commitment in SMEs. *Corporate Social Responsibility and Environmental Management*, 15 (5), 249–259.

Salaün, Y., and Flores, K., 2001. Information quality: meeting the needs of the consumer. *International Journal of Information Management*, 21, 21–37.

Sanne, C., 2002. Willing consumers- or locked-in? Policies for a sustainable consumption. *Ecological Economics*, 42 (1–2), 273–287.

Seuring, S., and Müller, M., 2008. From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, 16 (15), 1699–1710.

Sharfman, M.P., *et al.*, 2009. The road to cooperative supply-chain environmental management: trust and uncertainty

among pro-active firms. *Business Strategy and the Environment*, 18 (1), 1.

Sundin, E., and Bras, B., 2005. Making functional sales environmentally and economically beneficial through product remanufacturing. *Journal of Cleaner Production*, 13 (13), 913–925.

Thun, J.-H., and Muller, A., 2010. An empirical analysis of green supply chain management in the German automotive industry. *Business Strategy and the Environment*, 19 (2), 119.

Tukker, A., 2006. Identifying priorities for environmental product policy. *Journal of Industrial Ecology*, 10 (3), 1–4.

Ulrich, K.D., and Eppinger, S.D., 2008. *Product Design and Development*. Fourth edition. New York: McGraw-Hill.

Verganti, R., 2009. *Design-driven innovation. Changing the rules of competition by radically innovating what things mean*. Boston, MA: Harvard Business Press.

Young, A., and Kielkiewicz-Young, A., 2001. Sustainable supply network management. *Corporate Environmental Strategy*, 8 (3), 260–268.

Paper III

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Paper IV

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SUCCESS CRITERIA FOR IMPLEMENTING SUSTAINABILITY INFORMATION IN PRODUCT DEVELOPMENT

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ABSTRACT
The novel contribution of this article is the result of one group creativity session with product designers in the automotive supplier industry with the purpose of developing success criteria for the implementation of sustainability information. The sustainability information is organized with relevant information from each stakeholder, and may be used to support and strengthen sustainable product development in addition to using traditional product and process data. 79 unique ideas were identified by the group participants, 60 of these ideas being both feasible and relevant for implementation purposes. These 60 ideas were then grouped into nine categories. The ideas generated from the participants range from traditional implementation issues such as management commitment, customer or regulatory demands, and sufficient competence within sustainability issues, to more novel ideas including the development of a task force for sustainable development within the industrial cluster that the case firms are part of. Moreover, increased collaboration with academia was emphasized as important for the successful implementation of sustainability information in firms.

Keywords: sustainability information, sustainable product development, automotive supplier industry, brainwriting, success criteria.

1 INTRODUCTION
Whether firms should consider their social and environmental responsibility and the impact their activities have on stakeholders is no longer up for discussion [1]. The question now is rather how to integrate sustainability issues in day to day decisions and actions, as in product development. Unsustainable consumption, global climate changes, water and air pollution are forcing firms to rethink how they deal with competitiveness and shareholder values. Firms are increasingly facing pressure from government regulations, customer demands, competitors' actions and non-governmental organizations (NGOs) to improve their overall social and environmental performance [1-4].
The automotive industry in particular plays an important role, as there are few industries as large, influential, and diverse [5]. It affects global environmental and social development as its product systems directly and indirectly impact the natural and human environment along all stages of the product life cycle. At the same time, the automotive industry contributes considerably to economic growth and wealth creation and provides personal mobility for millions [4-6]. Today, environmental excellence is considered an order qualifier rather than order winner in the automotive supplier industry.
Within the field of product development, the contribution to sustainability from researchers and practitioners has traditionally been in the development of new tools and methodologies for ecodesign and sustainable product development [7-10]. Less attention has been given to stakeholders' influence and collaboration in product development and the information exchange between them. In seeking to improve product development in the automotive supplier industry, more and relevant information on sustainability issues is needed for day to day decision support. However, sustainability information relevant for product development is not necessarily available within the organizational borders of a firm [7, 11, 12]. Such a wider perspective is challenging as firms may not be willing to share information for proprietary reasons. Moreover, firms themselves may not be aware of which information could be of importance to them.
Sustainability information is defined in this article to be any kind of relevant information that may increase a firm's ability to develop sustainable yet commercially viable products. Sustainability

information explicitly includes information beyond mere internal product and process related data that is increasingly commonly used in product development processes. Such relevant sustainability information may already be readily available in domains such as sustainable supply management, consumer research, stakeholder management programs, or in the public regulations domain. Relevant sustainability information in this respect may be consumer preferences for services and "satisfaction" instead of physical products, competitors' corporate social responsibility programs, competitors' products' environmental performance, suppliers' labor practices (child labor, forced labor), non-governmental organizations' "black lists" with environmental claims towards firms or products, financial institutions' environmental risk checklists for lending, public procurement policies or sustainability expectations from firm stakeholders towards a firm and its products.

This article builds on previous research; an earlier exploratory case study [13] and multiple additional case studies performed in the Norwegian automotive supplier industry in 2010 [14]. The exploratory case study was carried out in 2009, with the purpose of investigating if potentially important information remained unconsidered in the product development process by firms. Several significant sources of relevant sustainability information were identified, while some of this information was not used to support product developers in their work. The multiple case studies were valuable input to the theoretical and practical development of how sustainability information may be used, and suggested its relevance for sustainable product development in the automotive supplier industry. By drawing on the results from this previous research, the novel contribution of this article is to present the method used as well as the results of a brainwriting workshop session with product designers from the automotive supplier industry. The purpose of the brainwriting session was to develop success criteria for the use of sustainability information in product development in the automotive supplier industry.

This paper continues by outlining the background of and the theoretical development of a sustainability information framework, followed by a brief presentation of idea generation methods useful to enhance group creativity. Section 3 outlines the research methodology applied, followed by the results of the workshop and discussion of these results.

2 ESTABLISHING A SUSTAINABILITY INFORMATION FRAMEWORK AND PREPARING IMPLEMENTATION

The purpose of a sustainability information framework is to specify relevant information that will strengthen and support sustainable product development in firms more than by just using conventional, product and process oriented data. The ensuing sustainability information has been identified through extensive literature search in *Science Direct* and a review of extant scientific literature. Based on more than 95 journal articles from 2000-2010, a review has been made of information that could be relevant for sustainable product development [14]. Stakeholder theory was used as a framework for categorizing and reviewing the different types of sustainability information, and for developing guidelines for using the information. Sustainability information from *internal* (management, employees, unions) and *external* (shareholders, financial institutions, competitors, customers, NGOs, media, government, industry associations, academia, suppliers) stakeholder groups were included to ensure that important information was not omitted. As the relationship between a firm and its stakeholders is characterized by a mutual exchange process of money, goods, information and expectations [15], our scope of interest in this respect was the information and expectation exchange within product development.

The process of going from a general framework to an industry-specific sustainability information framework was carried out through multiple case studies in 2010 [14]. Semi-structured interviews with product designers in the Norwegian automotive supplier industry were conducted to narrow down and customize the guidelines. The results from these interviews are shown in Table 1.

Table 1: Sustainability Information relevant for the Automotive Supplier Industry

Stakeholder	High Importance Sustainability Information relevant for Product Development
Government	Information on mandatory requirements under the End-of-Life Vehicle (ELV) Directive.
Government	Information on national regulations and priorities within Integrated Pollution Prevention and Control (IPPC).
	Information on proactive actions to pre-regulations (new regulations).

Stakeholder	High Importance Sustainability Information relevant for Product Development
NGOs	Information on requirements for environmental certificates managed by NGOs (e.g. ISO 14001).
Supplier	Information on innovation abilities.
	Information on service, price, quality, cost and delivery.
	Information on honesty, trust, respect and fairness in corporate or organizational relations (e.g. avoid bribery and corruption).
	Information on use and volume of hazardous substances in the product or packaging.
	Information on adherence to international, national and local legislation in addition to voluntary initiatives in sustainability matters (e.g. EMAS, ISO 14000-series).
	Information on financial situation and stability.
	Information on use of recyclable materials in products.
	Information on local labor practices (child labor, forced labor, discrimination, wage issues, working hours, workplace health and safety issues, employee privacy, access to food, water and healthcare).
	Information on investment in education and employee training programs.
	Information on adherence to UN's Human Rights Declaration.
Customer	Information on perceived personal benefits from acquiring and using the product.
	Information on the ability to be engaged in the activity of "doing" with the product, the preference of intelligent products in terms of constitution and functioning.
	Information on what affects and influences purchase decisions - delaying or avoiding making purchases.
	Information on preferences for green products from green firms.
	Information on fashion and trends within the product segment - trend sensitivity.
	Information on use of current products available on the market or similar products (focus on interface between human health, product/object, monitoring of direct impacts from the product (positive/negative) with respect to social, environmental and economic aspects during use).
	Information on environmental perception as to the product (i.e. is the product considered better/worse than similar products on the market).
	Information on environmental pressure towards firm.
	Information on sustainable and environmental performance requirements relevant to the product.
	Information on lock-ins and habits.
	Information on perception of firm image communicated through corporate social performance, responsibility and responsiveness, EMS and voluntary adherence to standards (e.g. EMAS, ISO 14001).
Competitor	Information on communication and marketing material available to the public, including advertisements on web-sites, newspapers, magazines etc.).
Academics	Providing knowledge exchange on sustainability matters.
	Information on priority settings for new and prioritized research areas, and national and international research calls.
Industry Associations	Information on sustainable technologies.
	Information on current or pending (up-coming) legislation.
Internal Stakeholders	Information on internal total environmental costs defined as environmental protection expenditure (costs for prevention, disposal, planning, actions, damage repair….) and material flow cost (costs for unutilized materials, energy, capital and personnel…).
	Information on internal commitment to include service policies that are provided to the customer during the use phase of products (to improve eco-efficiency and prolonged life of product) and to provide update policies.
	Information on internal freedom of speech, open information in the firm, transparency in firm decision making.
Internal	Information on internal investments in environmental technologies.

Stakeholder	High Importance Sustainability Information relevant for Product Development
Stakeholders	Information on internal adherence to requirements of social issues (SA 8000).
	Information on internal adherence to the requirements of ISO 14000-series standardization and EMAS (including Environmental Performance Indicators, Management Performance Indicators, Operational Performance, etc.)
	Information on internal commitment to involve users (stakeholders) in product development to enhance organizational and individual learning.

The purpose of this article is the development of success criteria for the use of sustainability information in product development in the automotive supplier industry. In order to develop such criteria, we decided to tap into the knowledge of the people working with product development in the automotive supplier industry and let them come up with ideas on how this can be made to work in practice. An additional motive for involving product designers at this stage was also to create engagement, excitement, and a sense of ownership of the proposed solutions.

To facilitate the generation of ideas (quantity and quality) it was decided to arrange a workshop focusing on idea generation. Organizations that work with creativity often encounter problems like lack of persistence and a tendency to premature criticism of ideas that are generated within groups. Brainstorming and brainwriting are perhaps the best known methods of idea generating that overcome the above mentioned obstacles [16-20]. Brainstorming involves oral sharing of all ideas that come into mind without evaluation or criticism of the generated ideas. Despite its popularity, brainstorming as a technique has encountered problems with low productivity (unwillingness to share ideas), free-riding, and social loafing (my ideas are not important), production blocking (verbal traffic jams) and downward comparison (the lowest performers in the group become the standard) [16, 18, 19].

Brainwriting is a technique that overcomes many of the problems frequently encountered in brainstorming. Brainwriting facilitates exposure to others' ideas and at the same time provides for the opportunity to attend to one's own ideas [18]. As opposed to the oral sharing of ideas in brainstorming groups, brainwriting involves silent writing and sharing of ideas in groups. Brainwriting is also typically a more structured and constrained process. At the same time, a sense of competition and social pressure is induced by participants frantically passing around notes to each other. This is believed to generate even more ideas. The relatively low knowledge of brainwriting as a useful idea-generating technique in organizations may be due to the fact that managers are inclined to leave their comfort zone in order to experiment with alternative approaches, if they are aware of the fact that alternative approaches exist [16].

Productivity is the main objective of brainstorming and brainwriting sessions, however, idea quality is considered to be just as important. Quality within creativity is by many researchers defined as a combination of originality (to which degree an idea is innovative and novel) and appropriateness (to which degree an idea is relevant to the topic and is feasible) [16, 17]. Other quality criteria may include *relative advantage* ("the degree to which an innovation is perceived as being better than its precursor"), *compatibility* ("the degree to which an innovation is perceived as being consistent with the existing values, needs and past experiences of potential adopters"), *complexibility* ("the degree to which an innovation is perceived as being difficult to use"), *observability* ("the degree to which the results of an innovation are observable to others") and *triability* ("the degree to which experimentation is possible before adoption") [16] . Overall, the quality criteria for brainstorming and brainwriting are somewhat vague and include to a great extent subjective judgements.

Due to the many limitations and obstacles associated with the brainstorming method, we decided to conduct a brainwriting idea-generation workshop in our research project. As the brainwriting method also was new to the product designers, one of the benefits of the workshop was organizational learning for the firms involved. The following section describes the brainwriting method that was used during the workshop.

3 RESEARCH METHODOLOGY

The initial selection of the automotive supplier industry as case was made because the industry is highly competitive, is international, and has global supply chains and highly demanding customers [21]. In addition, the automotive industry is also relatively developed in terms of environmental and sustainable performance due to pressures from government, NGOs and customers [4, 22], which is also important when performing research on sustainability related problems [23].

Little research examines the use of sustainability information in product development, let alone the implementation issues related to the successful use of such information in firms. We chose a case-based approach with workshop session and interviews to shed light on the implementations issues. Prior to conducting the research, a research protocol including brainwriting guidelines and an interview protocol was developed based on the identified sustainability information. The research protocol was pretested and piloted with academic faculty to help ensure the validity of the protocol.
The main purpose of the brainwriting session was to generate high quality ideas as to how sustainability information use in product development can successfully be implemented in firms. The brainwriting 6-3-5 method involves 6 people writing 3 ideas in 5 minutes. Among the workshop participants were also interviewees from the initial process of mapping potentially relevant sustainability information. The participants hold competence within product design and development, research and development, purchase, and logistics. The reason for inviting different competences to the workshop was to stimulate creativity through the presence of different professional backgrounds, knowledge and experience [16].
The participants were asked to write down 3 ideas in 5 minutes with concise and complete sentences on blank work sheets containing a problem statement. After 5 minutes, the worksheets were then passed on to the person on the right, unedited. Now, the session was repeated. The participants were free to use the ideas already written on the passed on sheets as triggers, or to ignore them as the sheets changed hands, as the exposure to other ideas is cognitively stimulating, and a positive sense of competition and social pressure between group members may be achieved by passing on the sheets this way [16]. The process of writing ideas and passing sheets was continued until all the work sheets were completed.
After the idea generation phase was completed, the work sheets were shared among the participants and the ideas were briefly discussed. After a clarifying session, the participants were given three points for ranking the three most important ideas that had come up during the session.
In order to verify the results, two additional interviews with product designers were performed after the workshop. New ideas to facilitate the implementation process were not identified during the interviews; the interviews did however to a great extent verify the results from the brainwriting session. Moreover, interview records from previous interviews with the same people on implementations issues were reviewed to complete the picture. Field notes were written up sequentially during the brainwriting session and during the interviews in order to record relevant discussions and comments from the participants.

4 RESULTS AND DISCUSSION

The ideas generated in the workshop, were coded and analysed in a tabular. The purpose of the coding process was to group ideas into logic categories. We used an inductive approach to develop the categories, i.e. developing and deriving categories from the material by means of generalization; observation – result – rule [23]. The success criteria identified were also reviewed in light of the additional semi-structured interviews conducted and the field notes from the workshop session. This process was repeated several times in order to ensure correct coding of the data into appropriate categories.
The workshop session was successfully completed with the generation of a total of 111 ideas. Some of the ideas were however overlapping or very similar but using different wording. The numbers of unique ideas calculated by excluding repetitive ideas were found to be 79. Simply generating a large number of unique ideas was not the main purpose of the brainwriting session. We also wanted to generate high quality ideas, i.e. ideas that were truly novel, useful and effective for implementing sustainability information [16, 17]. To this end, feasibility and effectiveness for implementation were considered most important. Hence, a coarse assessment to this effect to this was carried out.
Table 2 summarizes the main success criteria for implementing sustainability information in product development, as proposed by the participants in the brainwriting session. The success criteria ranked as most important during the workshop are presented first. The complete list of results may be shared with other researchers upon request.

Table 2. Main success criteria for implementing sustainability information in firms

Main success criteria according to idea categories	Number of	Number of	Number of

	ideas within category	feasible ideas	ideas relevant to the topic
1. The use of sustainability information must be driven by management commitment.	15	15	14
2. The use of sustainability information must be linked to economic performance and shareholder value within the firm.	9	9	3
3. The use of sustainability information must be driven by (new) stricter requirements from public authorities.	16	14	10
4. Academia must be a driving force for the use of sustainability information by passing on and communicating information and new developments within research, and up-coming requirements relevant to product development.	9	7	6
5. The use of sustainability information must be driven by customer demands and requirements.	11	10	9
6. The use of sustainability information must be driven by the establishment of an in-firm task force for sustainability issues.	3	3	3
7. The use of sustainability information must be driven by the establishment of a task force for sustainable development within the industrial cluster for exchange of experience and knowledge.	4	4	4
8. The use of sustainability information must be integrated in existing internal procedures and work processes.	7	7	6
9. The successful use of sustainability information is dependent on high internal competence on sustainability issues.	5	5	5
Total numbers	**79**	**74**	**60**

During the workshop, it was noticed that the quality and novelty of the ideas dropped as the workshop session proceeded. There was also a tendency to not coming up with new ideas, but only making minor contributions to previous ideas as time passed. Nevertheless, we consider 79 unique ideas as a good result. 74 of the ideas were considered feasible, that is, possible to implement. 19 of the ideas were during the analyzing process, not considered relevant for implementing sustainability information. Ideas that were ruled out during this process typically included concrete actions for making the firms themselves more sustainable, for example to reduce energy usage. One plausible reason for this confusion might be that working with sustainability issues is quite new to many product designers. For this reason, differentiating between implementing sustainability information and concrete sustainability actions on firm level might be difficult for them.

4.1 Management commitment (1)

Management commitment is always important when introducing something new to organizations. What management does, not what it says, quickly becomes the accepted norm in firms. The participants emphasized the will and determination on management level to invest in sustainable solutions as an important signal in this respect, for example by giving product designers time to invest in the search for relevant sustainability information. It will also be essential that sustainability issues are made part of all management meetings, and that concrete product improvements and results with regards to sustainability are demanded on such meetings as part of continuous improvements in the firms, as continuous improvements are the backbone of all activities in the automotive industry. The idea of linking management bonuses to sustainability achievements also came up as a way of to ensuring management commitment. Previous research in the electronics industry concerned with the dissemination of ecodesign information in firms has also identified good management commitment and support as an important success factor [24].

4.2 Economic performance (2)

Linking the use of sustainability information to economic performance and shareholder value within a firm is a reliable way of ensuring management focus. The participants emphasized that managers on all levels dominantly focus their priorities and activities on the performance indicators they are evaluated against. Consequently, developing financial indicators linked to sustainable product development performance (product improvements) and indirectly the use of relevant information (process improvement) came up us ideas to ensure priority. Literature suggests that sustainability may create financial value for a firm through increased revenues and lower costs. Revenues may be enhanced though increased sales due to improved firm reputation, and costs may be lowered due to process and product improvements [1]. As such, performance indicators clearly demonstrating the economic value of sustainability as area of priority will be important.

4.3 Stricter governmental requirements (3)

Still, many firms regard sustainability issues as a hindrance instead of a competitive advantage. Such a view is often accompanied by a strong belief that firm level sustainability actions (e.g the development of more sustainable products) can only follow from stricter governmental requirements and demands. Indeed, this view was overall shared by the participants. As firms struggle to keep track of new regulations on national and international level, the participants came up with the idea that implementing the use of sustainability information would be easier if the firm has easy access to up-to-date information on regulations. Relevant information could be made available from newsletters or specific websites. To further motivate firms to use sustainability information and improve their sustainable product development practices, it was also suggested to establish governmental national prizes for "best in class" on sustainability issues. A corresponding "black list" for poor performers in sustainable product development was also emphasized to further motivate firms. The "best and worst in class" lists could for example be determined based on auditing and self-reporting.

4.4 Academia (4)

Academia as an important driving force for providing general sustainability information to firms was suggested during the idea generating phase and during discussions. Firms find it hard to keep up to date with all new and up-coming regulations that potentially could be relevant to sustainable product development. Moreover, firms seldom have the required resources or competence to keep track of all relevant regulations. As a result, several ideas as to how academia could help firms in this context came up during the workshop: 1) establish industry specific websites with important sustainability information and news, 2) arrange sustainability related courses for industry partners, 3) establish an industry cluster task force for sustainable development for exchange of ideas, information, and lessons learned, and 4) initiate sustainability related research projects where knowledge development, and creation based industry needs are focused. It is important to emphasize that information potentially provided by academia will be general in its form. There is a lot of information specific to firms regarding customers, competitors, and suppliers that is unavailable to academia. Thus, this will be a job for the firms themselves or the consultants they hire.

4.5 Customer demands (5)

Not surprisingly, customer demands and requirements for more sustainable products were considered important with regards to implementation of sustainability information. The additional interviewees went even further by emphasizing that all changes in the automotive supplier industry must be driven by customer demands. A total of 9 unique, feasible and relevant ideas were identified in this category. The workshop participants made an important point by emphasizing the fact that customer requirements and demands can be altered and modified through closer customer collaboration, information and competence building. Ideas like pointing out feasible improvements in functionality, quality and competitiveness (added value), or by demonstrating the potential for reduced costs and price reductions for the customer through sustainable product development, are also expected to make the customer more receptive towards changing contractual requirements in favour of sustainability requirements. Being proactive, firms can negotiate and implement more sustainability requirements in future contracts to gain more right to decide which suppliers, materials, and substances to use and consequently be able to make a bigger impact. This is in line with other researchers who suggest that a

firm's ability to minimize its environmental impacts during product design is often dependent on the firms capability to manage supplier relationships [25].
In spite of the many implementation ideas in relation to customers and the high emphasis on customers in the workshop discussions, we notice that internal factors such as management commitment and linking the use of sustainability information to economic performance were in sum ranked higher. One plausible explanation could be that firms unconsciously have a higher degree of influence on the use of sustainability information than they will admit. It is always easier to point to external factors like regulations, customers, or academia for the implementation and use of information, than making the actual in-firm changes themselves. On the positive side, this result indicates that the firms themselves are in the driving seat and influence to a great extent whether the implementation of sustainability information is successful or not.

4.6 Task force establishment (6, 7)

The establishment of an in-house task force for sustainability issues in future development projects can be used to drive the implementation of the use of sustainability information according to the product designers. The use of teams in organizations is a good way of ensuring that sustainability issues are given the necessary attention, support, and practical assistance in projects, especially in a starting-up period. In regard to this category, the designers also emphasized that such a task force should be established at all geographical locations of the firms, that academia should be used to elevate the overall sustainability competence of the task force, in addition to the importance of management commitment to the task force by asking for and demanding sustainability related results. The same ideas also emerged in relation to the establishment of an industrial cluster task force, were in addition, possible synergies due to sharing of information, and working with the same issues were emphasized by the group. According to literature, the use of task forces is not new, and several positive effects by engaging in such teams may be identified:1) assigning a collective responsibility may avoid "fire fighting", 2) involving everyone affected ensures that any solutions found and actions taken are acceptable to everyone in the project, 3) time can be saved as the work is carried out cross-functionally and not sequentially be each department, and 4) organizational culture and work climate can be improved through wide involvement [26].

4.7 Integration into existing processes (8)

Another important success criterion identified for the use of sustainability was to make sustainability information part of the already existing work processes and procedures through check lists for design reviews and gate models, and to make the information part of the internal product design meetings. The adaption to existing firm processes could be made possible by applying for internal investment funds to complete the change. One should also make a point of documenting all projects and activities concerning sustainability actions to facilitate focus on continuous improvements within the organization. Internal audits to verify that sustainability information is actually being used in product development should also be performed. Literature on success factors for ecodesign implementation also underlines integration of environmental issues into existing product development processes as important [27].

4.8 Sustainability competence (9)

The product designers also emphasized competence on sustainability as important for the successful implementation of sustainability information in product development. The use of "sustainability champions" with special education and training to help co-workers in their sustainability work was suggested by the participants. Another suggestion was to use firm intranet to educate and elevate sustainability competence within firms. Moreover, the firms could apply for new research projects through national competence building programs. The use of champions or experts is a well-known method for implementing changes in organizations [27].

5 CONCLUSION

The starting point of this research project was to develop success criteria for the implementation of sustainability information. As the automotive industry is under growing pressure from both public governments and customers to develop more sustainable products, the use of sustainability information as defined in the article is expected to support and strengthen firms' product development

processes. The information can be used in addition to traditional product and process data in decision making processes in product development, but also other operations as i.e. procurement and production is expected to be effected by the use of it.
To prepare implementation process in the automotive supplier industry, a brainwriting workshop was arranged. 79 unique ideas to help implementation were identified by the participants, 60 of these ideas were considered to be both feasible and relevant. The ideas included traditional implementation aspects as management commitment, customer or regulatory demands and sufficient competence within sustainability issues. It was emphasized by the participants in the workshop that it was essential that the guidelines were included in the already existing work processes and procedures to be used. This includes design review meetings, gate models and internal audits to ensure and verify that the guidelines actually are being used. Other more novel ideas generated included linking the guidelines to economic performance and shareholder value. A good business case that clearly demonstrates the connection between sustainability aspects and economic figures will help ensure commitment also from different management levels. Perhaps the most novel ideas were in connection with the development of a task force for sustainable development within the industrial cluster that the case firms are part of, as well as connecting this task force with academia to generate synergistic effects. Learning from other firms through "lessons learned" and best practices is always fruitful, and when this is linked with increased collaboration with academia, a powerful moment of force to "push" firms towards sustainability is established.
Based on the results of the research project, we highly recommend firms to start the implementation process of sustainability information by using the success criteria as presented. The use the criteria is expected to facilitate the implementation process, and the subsequent use of sustainability information is expected improve the sustainability performance of products. A future research path we hope to follow is to investigate the effectiveness and success of the criteria during implementation in automotive supplier firms.

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REFERENCES

[1] Epstein, M.J. *Making sustainability work - Best Practices in Managing and Measuring Corporate Social, Evironmental and Economic Impacts*, 2008 (Greenleaf Publishing).
[2] Delmas M., Toffel M.W. Stakeholders and environmental management practices: an institutional framework. *Business Strategy and the Environment*, 2004, 13(4), 209-222.
[3] Madsen H., Ulhoi J.P. Integrating environmental and stakeholder management. *Business Strategy and the Environment*, 2001, 10(2), 77-88.
[4] Kantz, O. Volvo's holistic approach to environmental strategy. *Corporate Environmental Strategy*, 2000, 7(2), 156-169.
[5] Orsato, R.J., Wells P. The Automobile Industry & Sustainability. *Journal of Cleaner Production,* 2007, 15(11-12), 989-993.
[6] Koplin, J., Seuring S. and Mesterharm M., Incorporating sustainability into supply management in the automotive industry - the case of the Volkswagen AG. *Journal of Cleaner Production*, 2007, 15(11-12), 1053-1062.
[7] Baumann, H., Boons F., and Bragd A. Mapping the green product development field: engineering, policy and business perspectives. *Journal of Cleaner Production*, 2002, 10(5), 409-425.
[8] Ilgin, M.A., Gupta S.M. Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art. *Journal of Environmental Management*. 2009, 91(3), 563-591.
[9] Karlsson, R., Luttropp C. EcoDesign: what's happening? An overview of the subject area of EcoDesign and of the papers in this special issue. *Journal of Cleaner Production*, 2006, 14(15-16), 1291-1298.
[10] Hauschild, M., Jeswiet J., and Alting L. From Life Cycle Assessment to Sustainable Production: Status and Perspectives. *CIRP Annals - Manufacturing Technology*, 2005, 54(2), 1-21.

[11] Foster, C., Green K. Greening the innovation process. *Business Strategy and the Environment*, 2000, 9(5), 287-303.
[12] Srivastava, S.K. Green supply-chain management: A state-of-the-art literature review. *International Journal of Management Reviews*, 2007, 9(1), 53-80.
[13] Aschehoug S.H., Boks C. and Storen S. A framework for identification of environmental information among stakeholders, in *EcoDesign 2009 - 6th International Symposium on Environmental Conscious Design and Inverse Manufacturing*, Sapporo, Japan, Desember 2009.
[14] Aschehoug S., Boks C. Sustainability Information in Product Development – the Case of Automotive Supplier Industry, in *APMS 2010, Internation Conferance on Advances in Production Management Systems*, Cernobbio, Italy, October 2010.
[15] Andersen B., Fagerhaug T. *Performance Measurement Explained. Designing and Implementing Your State-of-the-Art System*, 2002 (ASQ Press, Milwaukee).
[16] Heslin, P.A. Better than brainstorming? Potential contextual boundary conditions to brainwriting for idea generation in organizations. *Journal of Occupational and Organizational Psychology,* 2009, 82(1), 129-145.
[17] Rietzschel, E.F., Nijstad B.A. and Stroebe W. Relative accessibility of domain knowledge and creativity: The effects of knowledge activation on the quantity and originality of generated ideas. *Journal of Experimental Social Psychology*, 2007, 43(6), 933-946.
[18] Paulus, P.B., Yang H.-C. Idea Generation in Groups: A Basis for Creativity in Organizations. *Organizational Behavior and Human Decision Processes*, 2000. 82(1): 76-87.
[19] Leggett Dugosh, K., Paulus P.B. Cognitive and social comparison processes in brainstorming. *Journal of Experimental Social Psychology*, 2005, 41(3), 313-320.
[20] McGlynn, R.P., et al. Brainstorming and task performance in groups constrained by evidence. *Organizational Behavior and Human Decision Processes*, 2004, 93(1), 75-87.
[21] Handfield, R., Sroufe R., and Walton S. Integrating environmental management and supply chain strategies. *Business Strategy and the Environment*, 2005, 14(1), 1-19.
[22] Thun, J.-H., Muller A. An empirical analysis of green supply chain management in the German automotive industry. *Business Strategy and the Environment*, 2010, 19(2), 119.
[23] Karlsson, C. *Researching Operations Management*, 2009 (Taylor & Francis).
[24] Boks, C. The soft side of ecodesign. *Journal of Cleaner Production*, 2006, 14(15-16), 1346-1356.
[25] Darnall, N, Jason G.N., and Handfield R. Environmental management systems and green supply chain management: complements for sustainability? *Business Strategy and the Environment*, 2008, 17(1), 30-45.
[26] Andersen, B. *Business Process Improvement Toolbox*, 2007 (ASQ Press, Milwaukee).
[27] Johansson, G. Success dactors for integration of ecodesign in product development - a review of state-of-the-art. *Environmental Management and Health*, 2002, 13(1), 98-107.

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Paper V

Building sustainability knowledge for product development and design – Experiences from four manufacturing firms

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Abstract: To further improve the sustainability performance of products, a framework for identification and compilation of sustainability information beyond mere product and process data has been developed. This has been done under the assumption that access to and use of such information may increase firm knowledge on sustainability issues as well as firm ability to develop sustainable products, and thus enhance competitiveness by adding value to products beyond functionality, quality, and cost. This article presents the results from four case studies in the Norwegian furniture and automotive supplier industry, identifying the categories of sustainability information which firms find most important and relevant to product development. Factors influencing accessibility of such information have also been identified. Systematically identifying and compiling sustainability information the way proposed by the framework is suggested useful for developing requirements and specifications, for general decision support, and for generating knowledge that may inspire entirely new product meanings.

Keywords: sustainability information, knowledge, product development and design, sustainable product development, case study, stakeholders, automotive supplier industry, furniture industry

1 Introduction

Firms are faced with increasing pressures from stakeholder groups to improve their sustainability performance, as consequences for social, environmental, and economic systems resulting from industrial activities and unsustainable consumption are becoming increasingly apparent. The question is no longer whether firms should consider the social and environmental impact their activities have on stakeholders, but rather how to integrate sustainability issues in day-to-day decisions, actions, and strategic priorities (Epstein 2008) like in product development and design.

In response, an increasing number of firms are evaluating the unsustainable impacts resulting from their products. Since up to 80% of environmental and social cost factors of a product are determined in the early phases of product development and design (Charter and Tischner 2001, Maxwell and van der Vorst 2003), these phases have been the target of much interest among researchers, as improvements to the sustainability attributes of a product can be made most effectively here. Many firms have to some extent succeeded in

improving the sustainability performance of their products by applying tools for ecodesign in their product development activities, mainly focusing on low hanging fruits like substitution of hazardous chemicals. However, taking sustainable product development and design to the next level may require a broader perspective than those of current industrial practices. Using more and other types of information to build knowledge on sustainability issues in product development and design may be an additional way for firms to improve the sustainability performance of their products.

Product development and design rests heavily on information to achieve its main tasks (Hicks et al. 2002) and may further be regarded as an information transformation process (Hubka et al. 1988). Information may be described as an element describing a fact (Hicks et al. 2002), or a flow of messages (Nonaka 1994), while knowledge is created and organized by this information flow founded in the commitment and beliefs of the holder (Nonaka 1994). Knowledge has also been described as the ability of individuals to understand information, including how they handle, apply, and use it in a given situation (Court 1995). Hence, seeking out relevant information on sustainability issues may be a key to increased sustainability knowledge in product development and design, which may further enhance firms' ability and opportunity to develop and manufacture more sustainable products. Sustainable products may be one way of adding value to products beyond functionality, quality, and cost, and thus increase firms' competitiveness.

Relevant information on sustainability issues does not just appear, but has to be identified, collected, and compiled before use (Erlandsson and Tillman 2009). As no similar concept was identified in existing scientific literature, sustainability information (SI) is here defined as *stakeholder information elements potentially capable of contributing to knowledge in product development and design by combining the environmental, social, and economic dimensions of sustainability.* SI explicitly includes information beyond mere product and process related data, as well as sustainability expectations from firm stakeholders, towards the product itself, or towards the firm (Aschehoug et al. 2009). This requires the involvement of a broad network of stakeholder groups. The SI definition is a synthesis of the triple bottom line (TBL) concept (Elkington 1998), information and knowledge theory (Nonaka 1994, Hicks et al. 2002), and stakeholder theory (Freeman 1984, Donaldson and Preston 1995, Andersen and Fagerhaug 2002).

In order to inquire into SI in a product development and design context, a research project funded by the Centre for Researched Based Innovation – Norwegian Manufacturing Future was initiated to explore the following research questions: 1) what sustainability information relevant to product development and design is considered important in manufacturing firms? 2) How accessible is this relevant information? 3) What are the factors influencing perceived importance and accessibility of such information in manufacturing firms? These questions are investigated by drawing on the results from two case studies in the Norwegian furniture industry and two case studies in the Norwegian automotive supplier industry conducted in 2009-2011, as well as on previous results from the research project (Aschehoug and Boks 2010, Aschehoug and Boks 2012, Aschehoug et al. 2012).

This article starts by outlining previous research within the field, leading to a brief introduction to the concepts and framework developed to study SI (Aschehoug and Boks

2012). The new research results and conclusions from the four case studies are then presented and discussed.

2 Theoretical background

Research explicitly examining SI in a product development and design context has previously been explored only to a limited extent. Calls for more information in a product development context have been made by several researchers (Foster and Green 2000, Baumann et al. 2002, Waage et al. 2005), calls in which information flows have been described as both patchy and incomplete. It has been suggested that information relevant to innovation and product development be identified from relevant actors and firm stakeholders (Foster and Green 2000, Baumann et al. 2002, Verganti 2008). The main body of literature, however, examines sustainability information in other contexts than product development. Sustainability information from firms to their stakeholders is examined in literature concerning sustainability disclosure (Larsen 2000, Frieder 2002, Line et al. 2002, McMurtrie 2005, Moffat and Auer 2006, Brown et al. 2009, Prado-Lorenzo et al. 2009, Tagesson et al. 2009). Others focus on IT systems for environmental information management (Carlson et al. 2001, Frysinger 2001), while some researchers have focused more on knowledge acquisition through stakeholders (Roy and Thérin 2008, Bos-Brouwers 2009). The most comprehensive work identified is a framework for corporate environmental information collection, management, and communication (Erlandsson and Tillman 2009). This framework sorts out what corporate environmental information is, and examines stakeholders as influencing factors, but does not do so in the context of product development.

As SI is scattered across fields, a new framework was developed grounded on stakeholder theory by combining information elements from the following fields: sustainable development and triple bottom line concept, sustainable consumption and consumer culture, corporate social responsibility, legislation (European Commission (EC) Directives, national and regional requirements), sustainability and environmental reporting initiatives, sustainable and green supply chain management, sustainable and green marketing, and sustainable product development and ecodesign. Examples of SI included in the framework are information on suppliers' labour practices (e.g. child labour, forced labour), competitors' marketing material on sustainability issues, financial institutions' environmental risk checklists for lending out money, and public procurement policies. The SI framework was developed to render studies on sustainability information in industrial practice possible, by including all firm stakeholders (not only supply chain actors), information elements beyond product and process data, and by addressing a broad range of economic, environmental, social, and ethical issues that are accessible in diverse ways.

As extensive amounts of information are used in product development and design processes (Hicks et al. 2002), it is important to single out the information elements that are truly useful to build knowledge on sustainability issues. This concerns information quality which was found to depend on the context, the problem at hand, as well as the information customer (i.e. information user). As no universal definition or criteria for information quality were identified (Forza and Salvador 2001, Salaün and Flores 2001,

Hicks et al. 2002, Lee et al. 2002, Uotila and Melkas 2007, Hartono et al. 2010), the criteria presented in Table 1 are used in the present research:

Table 1 Information quality criteria

Description	*Criteria*
Context: Product development and design	*Importance:* does the information element have the potential to be truly useful in product development and design? Can the information element potentially build knowledge on sustainability issues and thereby affect decisions or choices in problem analysis, conceptual design, embodiment of design, detailing, testing and refinement, or production and ramp-up?
Purpose: To build sustainability knowledge in product development and design	*Importance:* does the information element concern sustainability issues relevant to the case firm?
Customer: All disciplines and internal stakeholders involved in product development and design	*Accessibility:* is the information element obtainable for the information customer, i.e. does the customer regard the information as easily accessible?

The following section describes research conducted using the SI framework as point of departure for interviews in determining importance and accessibility of SI in relation to product development and design, and the main factors influencing these perceptions.

3 Research design

Four case studies in the Norwegian manufacturing industry were conducted. As selecting an appropriate sample is important in case research (Karlsson 2009, Yin 2009), four firms known to hold high environmental standards and interest in sustainability issues were selected. They also have in-house product development departments and manufacturing plants in Norway. Table 2 summarizes the main firm characteristics.

Table 2 Details of four case studies

	Automotive supplier A	*Automotive supplier B*	*Furniture C*	*Furniture D*
Main product	Break couplings	Plastic fittings	Office chairs	Sofas and arm chairs
No. of employees	203	168	366	940
Turnover (million)	US$433	US$36	US$165	US$430
Year of study	2010	2010	2011	2011
Formal interviews	5	4	6	10
Formal meetings	2	3	2	2
Informal contacts	Mail, telephones, brief encounters	Mail, telephones, brief encounters	Mail, telephones, brief encounters	Mail, telephones, brief encounters
Type of informants	-Product designers and engineers -Product development mng.	-Product designers and engineers -Product development mng.	-Product designers and engineers -Product development mng.	-Product designers and engineers -Product development mng.

	-Purchasing mng.		-Purchasing mng.- Env. mng.	-Purchasing mng. - Env. mng.

3.1 Data collection

For each case study, a research protocol describing data collection methods based on the SI framework was developed and pretested. All interviews were conducted at the case firms' locations using semi-structured interviews in which questions were formulated around each SI element from the pre-developed SI framework. The semi-structured interviews allowed for additional information being collected during the course of the interview, mainly around topics like: organization of product development and design projects, terminology and familiarity regarding sustainability issues in general, as internal information flows, current stakeholder interaction and collaboration, as well current practices regarding ecodesign. Several sources of evidence were collected during interviews to address construct validity (Yin 2009). Individual questions were also asked to multiple informants (Karlsson 2009). Field notes were written up sequentially following each interview.

3.2 Data analysis

The collected data were analyzed with the objective of identifying those information elements considered most important and most accessible to product development and design by the furniture and the automotive supplier industry respectively. This meant ranking the information elements with quantitative criteria, and to accumulate all interview results by industry sector. Additional information from the interviews (other than SI) was coded and analyzed in a matrix display for patterns and themes for similarities and differences between the furniture and the automotive supplier industry.

3.2 Data validity

The results presented in this article should be regarded as indicative only as the data collected in the case studies reflect the personal opinions of the firms' employees. The employees represented as presented in Table 1, are mainly concerned with operational product development and design tasks, and hence their answers reflect this view of the world. Other employees at corporate level may have responded differently to the questions, as they are inclined to be more concerned with long term strategic issues. The difference in answers reported by product development managers and product designers indicate such a difference. However, as the aim of this article is to identify information elements that may contribute to knowledge on sustainability issues in product development and design, not in the firm as a whole, this situation is not regarded as problematic.

4 Results case studies

With the initial SI framework as a basis, Table 3 on the following page presents the combined results from all four case firms. The table displays the most important information elements and their accessibility presented per stakeholder group for each

industry sector. Information elements perceived by interviewees as unimportant to product development and design are not included in this article but may be shared upon contact with the authors. Differences between industry sectors are highlighted in italics.

Based on the interviews, the industry sectors showed consensus concerning SI importance for the following stakeholder groups: academia, industry associations, and customers. The results varied more for the following stakeholder groups: government, NGOs, media, shareholders, financial institutions, suppliers, and customers.

Table 3 High importance SI in the furniture and automotive supplier industry respectively

Stakeholder group	*Furniture industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*	*Automotive supplier industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*
Government	-Pre-regulations (new regulations) concerning sustainability issues	H	-Pre-regulations (new regulations) concerning sustainability issues	H
	-National guidelines and priorities within Integrated Pollution Prevention and Control (IPPC)	H	-National guidelines and priorities within Integrated Pollution Prevention and Control (IPPC)	H
	-Export/import countries' sustainability regulations	H	*-Mandatory requirements under End-of-Life Vehicle (ELV)*	H
	-Purchasing guidelines and requirements for social and environmental responsible public procurement	H		
	-Mandatory requirements under Registration, Evaluation and Authorization of Chemicals (REACh)	H		
NGOs	-Requirements for sustainability-labelling or sustainability certificates managed by NGOs	H	-Requirements for sustainability-labelling or sustainability certificates managed by NGOs	H
	-Campaigns targeted at specific products, substances, firms, practices, or industries (negative information)	H		
	-Sustainable performance test results and ranking lists(NGOs' "black lists")	H		
Media	*-Interests, values, preferences, and dislikes related to a product or firm*	H		
	-Documentaries and campaigns targeted at specific products, substances, firms, or industries (negative information)	H		
Shareholders	*-Attitudes and values on sustainability issues*	H		
Academia	-Sustainability issues through	H	-Sustainability issues through	L

Stakeholder group	*Furniture industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*	*Automotive supplier industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*
	knowledge exchange, practice transfer (workshops, students), and research		knowledge exchange, practice transfer (workshops, students), and research	
	-Priority settings for new sustainability related research areas and calls	L	-Priority settings for new sustainability related research areas and calls	L
	-*Work and cooperation with standardization organizations*	H		
Industry Associations	-Sustainable technologies and other relevant sustainable issues	H	-Sustainable technologies and other relevant sustainable issues	L
	-Current or pre-regulations concerning sustainability issues	H	-Current or pre-regulations concerning sustainability issues	L
Competitors	-Communication and marketing material on sustainability issues	H	-Communication and marketing material on sustainability issues	H
	-*Adherence to legislation or voluntary sustainability-labelling or sustainability certificates/standards*	H		
	-*Corporate sustainability policies, management systems, and performance*	H		
Suppliers	-Use and volume of hazardous substances in product or in packaging	H	-Use and volume of hazardous substances in product or in packaging	L
	-Adherence to legislation or voluntary sustainability-labelling or sustainability certificates/standards	L	- Adherence to legislation or voluntary sustainability-labelling or sustainability certificates/standards	H
	-Honesty, trust, respect, and fairness in business relations	L	-Honesty, trust, respect, and fairness in business relations	H
	-Service, price, quality, cost, and delivery	H	-Service, price, quality, cost, and delivery	H
	-Innovation abilities and product development activities	H	-Innovation abilities and product development activities	H
	-Financial situation and stability	L	-Financial situation and stability	H
	-Use of reusable and recyclable materials	L	-Use of reusable and recyclable materials	H
	-Labour practices (SA 8000, fair labour code of conduct, and ILO's Decent Work standard)	L	-Labour practices (SA 8000, fair labour code of conduct, and ILO's Decent Work standard)	L
	-Adherence to the UNs Human Rights Declaration	H	-Adherence to the UNs Human Rights Declaration	L
	-*Local impacts on natural resources, land, and biodiversity at suppliers'*	H	-*Education and training programs for employees (sustainability related and*	L

Stakeholder group	*Furniture industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*	*Automotive supplier industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*
	production facilities		*other programs)*	
	-Energy use (non-efficient, non-renewable and non-sustainable sources of energy), or commitment to energy saving projects	L	*-Support of oppressive regimes*	L
	-Supplier's supplier selection programs and purchasing policy	L		
	-Sustainability communication with stakeholder groups, including communication of sustainable benchmark results to customers or markets (e.g. AA1000, GRI)	L		
	-Corporate sustainability policies and management systems	L		
Customers	-Perceived personal factors and benefits from the product (satisfaction), perceived product meaning	H	-Perceived personal factors and benefits from the product (satisfaction), perceived product meaning	H
	-Sustainability perception as to the product (e.g. if the product is considered better/worse than similar products on the market)	H	- Sustainability perception as to the product (e.g. if the product is considered better/worse than similar products on the market)	L
	-Behaviour in a social-cultural market context, what influences the purchase decision?	L	-Behaviour in a social-cultural market context, what influences the purchase decision?	H
	-Preferences for sustainable products from sustainable firms	H	-Preferences for sustainable products from sustainable firms	H
	-Fashions and trends within the product segment - trend sensitivity – the wish to have up-to-date products	H	-Fashions and trends within the product segment - trend sensitivity – the wish to have up-to-date products	H
	-Use of current product on market or similar products if product does not exist, with respect to sustainability aspects (lifetime, durability, reliability, upgrade options, maintenance requirements, and EOL scenarios)	L	-Use of current product on market or similar products if product does not exist, with respect to sustainability aspects (lifetime, durability, reliability, upgrade options, maintenance requirements, and EOL scenarios)	H
	-Lock-ins and habits of unsustainable practices	H	-Lock-ins and habits of unsustainable practices	H
	-Perception of firm sustainability image (reputation)	L	-Perception of firm sustainability image (reputation)	H
	-Sustainable performance requirements towards delivered	H	-Sustainable performance requirements towards	H

Stakeholder group	*Furniture industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*	*Automotive supplier industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*
	product or service		delivered product or service	
	-Preferences for services instead of physical products. Social barriers towards shared use of products or open-mindedness towards renting and shared use.	L	*-Ability to be engaged in the activity of "doing" things with the product, the preference for intelligent products*	H
Internal Stakeholders	-Labour practices (SA 8000, fair labour code of conduct, and ILO's Decent Work standard)	H	-Labour practices (SA 8000, fair labour code of conduct, and ILO's Decent Work standard)	H
	-Adherence to sustainability standards (e.g. ISO 14000-series)	H	-Adherence to sustainability standards (e.g. ISO 14000-series)	H
	-Freedom of speech and open information in firm	H	-Freedom of speech and open information in firm	H
	-Commitment to transparency in firm decision making	H	-Commitment to transparency in firm decision making	H
	-Commitment to use effective environmental accounting systems and management tools with performance indicators (e.g. TBL accounting, LCA, EPD, GRI)	H	-Commitment to use effective environmental accounting systems and management tools with performance indicators (e.g. TBL accounting, LCA, EPD, GRI)	H
	-Internal investments in sustainable technologies	H	-Internal investments in sustainable technologies	H
	-Commitment and adherence to corporate sustainability policies and management systems	H	*-Commitment to include service policies to customers during the use phase of the product (to improve eco-efficiency and prolonged life of product) and provide customers with updated policies for products*	H
	-Adherence to sustainability-labelling (e.g. EU Flower, EU Energy Label, Nordic Swan, German Blue Angels, Forest Stewardship Council, Marine Stewardship Council, Fair Trade, Energy Star, etc.)	H	*-Commitment to involve users and other stakeholders in product development to enhance organizational and individual learning*	H
	-Education and training programs for employees (sustainability related and other programs)	H		
	-Impacts on local natural resources, land, and biodiversity at production facilities	H		
	-Commitment to advertising	H		

Stakeholder group	*Furniture industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*	*Automotive supplier industry Description of sustainability information element ("information on……")*	*Access High (H) Low (L)*
	norms, i.e. responsible marketing (e.g. green washing, not provide damaging offers)			
	-Motivational activities towards customers to promote recovery of products and components for reuse, recycling, or treatment/disposal, and to keep records of and track where the firm's products are (EOL instructions)	H		

EOL = End of Life, ILO = International Labour Organization, AA1000 = AccountAbility standard, GRI = Global Reporting Initiative, SA 8000 = Social Accountability standard, TBL = Triple Bottom Line, LCA = Life Cycle Assessment, EPD = Environmental Product Declaration

4.1 Discussions: sustainability information importance

SI on regulations in general and information on upcoming regulations in particular was considered very important in both industries. The firm interviewees emphasized that adapting to pre-regulations in product development and design was considered a competitive advantage. In general, all "early warning" information elements from governmental and standardization bodies were perceived as important to sustainable product development and design, in addition to current regulations and standards.

Differences concerning importance considerations within the governmental domain may be explained by *different business contexts (products) and customers*. First, the automotive industry highlighted the EVL directive as important while the furniture industry highlighted REACh as more interesting, based on their current product portfolios. Second, the automotive supplier industry is strictly ruled by the customer (Ringen 2010), i.e. the automotive car makers pose strict requirements on their suppliers, including sustainability issues. As a consequence, SI on export/import countries' environmental regulations for instance, was reported as incorporated into customer requirements. In the furniture industry, however, the firms reported that they have to identify such SI themselves. Furniture industry customers are either private consumers or institutional customers who do not have the competence or the possibility to forward requirements including SI they way automotive customers do.

Yet another difference concerns purchasing guidelines for sustainable responsible public procurement, which is considered very important to the furniture manufacturers with institutional customers, especially firm C. Such guidelines are forwarded to the manufacturers every time large public procurements are made and vary between projects, regions, and countries. These guidelines are stored and continuously incorporated into product specifications to ensure that all products fulfil the most stringent requirements. If such guidelines at all were relevant to the automotive supplier industry, they would be incorporated into customer requirements.

A significant difference between the industry sectors can be noticed in SI importance concerning NGOs and media. Other than requirements for sustainability-labelling and sustainability certificates which were considered a prerequisite in product development and design in both sectors, other SI elements were not considered important to the automotive supplier industry. SI about campaigns targeted at specific products, substances, firms, practices, or industries were for instance not considered important. This is in contrast to findings in the furniture industry. Different *supply chain positions* may be one factor accounting for these differences. The furniture manufacturers are the focal firms in their supply chains. As other researchers have pointed out, it is the focal firm that receives media or NGO attention regarding social or environmental problems in earlier supply chain stages (Seuring and Müller 2008). Such attention may lead to reputation loss and loss of customers (Kong et al. 2002). As the car makers are the focal firms in the automotive supply chain, the automotive suppliers themselves face a lower risk of being exposed to social or environmental disclosure. Consequently, SI from stakeholders' like media and NGO are perceived less important.

Both industry sectors rated SI from academia as important. Current and previous collaboration with academia on research projects have given the firms hands-on *experience on SI usefulness* from this stakeholder group. Academia as important "knowledge brokers" were highlighted by all firms, as the firms do not themselves have the necessary resources to keep up to date. Research institutions as suppliers of knowledge have also previously been reported in literature (Roy and Thérin 2008, Bos-Brouwers 2009). According to the case firms, industry associations are viewed as equally important suppliers of SI relevant to product development and design, although industry associations may provide different types of SI than academia. SI from academia was regarded as more general than the more specific SI that industry associations could provide (e.g. SI on best available technologies (BAT) for sustainable production). Academia was also regarded as less proactive suppliers of SI than the corresponding suppliers of SI among industry associations.

Both industries acknowledged the importance of competitors' sustainability marketing material to product development and design, whereas information about adherence to sustainability standards and corporate sustainability policies where regarded as important only in the furniture industry. Knowing your competitors' stance in sustainability issues is indeed important, as such information, among other factors, can be used to improve products (Boks and Stevels 2003). *Dissimilar business contexts* may to a great extent explain differences in importance ranking within the competitors' domain. The automotive supplier industry is dominated by long term contracts, often 7 years or more, in which sustainability performance is considered order qualifier rather than order winner. Hence, all relevant sustainability requirements are incorporated into customer requirements and bids to tender. As a consequence, other SI in general, and competitors' SI in particular was mostly considered "nice to have" in the automotive supplier industry, and most relevant when competing for new contracts. This reactive attitude observed in the automotive supplier industry may result in missed opportunities for adding value to products through sustainability beyond functionality, quality, and cost.

In the suppliers' domain many similar information elements were considered important to product development and design in both sectors. Among them, all three TBL-elements were represented. The furniture industry, however, ranked more SI as

important than did the automotive supplier industry. All four case firms reported to practice the "back to back" principle; they check their suppliers and their suppliers' systems for checking other suppliers upstream the supply chain, and so on. What differentiates the two industry sectors was mainly their code of conduct documents, their ethical standards stating supplier obligations, and above all, their *adherence to voluntary supplier sustainability initiatives*. Firm C adheres to Ethical Trading Initiative-Norway, whereas Firm D adheres to the UN Global Compact. Firm C reported examples of suppliers from low cost countries being terminated from development projects due to poor working conditions in suppliers' factories. Firm D on the other hand, deliberately sourced parts and materials among acknowledged suppliers from Scandinavia or Europe to possibly avoid such problems. Both firms in the furniture industry argued that if follow-up costs, cost of poor quality, and transportation costs were added to the purchasing cost of sourcing parts in low cost countries, then the price difference in their product segment (i.e. premium brand furniture) was marginal.

The cost issue was perceived to be more prominent in the competitive automotive supplier industry, premium brand or not. Parts and material suppliers are sourced from all over the world, predominantly based on purchasing costs. Ethical standards, code of conduct documents, and customer requirements guide automotive supplier initiatives, but presently, this industry sector does not go beyond the above to voluntary sustainability agreements as does the furniture sector.

This largest surprise in the research project came when analyzing customer information elements. The furniture manufacturers are business to consumer firms; they have private consumers or institutional end-customers. The automotive suppliers on the other hand are business to business firms and supply parts to automotive car makers. Considering this great difference in customers, a corresponding great difference in SI importance ranking in the customer domain was predicted. This was not the case. Only two information elements differentiated the industries. This result could indicate that tending to customer needs is to some extent universal, and independent of customer position in the supply chain. The authors have, however, not succeeded in locating other research supporting such findings. On the other hand, the SI described is quite general, and as such, the differences may first appear when more specific and detailed customer needs and wants are identified on firm level.

The furniture industry regarded more SI in the internal stakeholders' domain as important, than did the automotive suppliers. Differences in *sustainability strategies and goals* may explain this difference. The furniture industry has clearly communicated product level sustainability goals. On the other hand, the automotive supplier industry has not mentioned product level sustainability goals at all, but focuses more on overall health, safety, and environmental (HSE) issues concerning the manufacturing process in their steering documents. Moreover, the furniture industry emphasized during interviews that premium product sustainability performance was considered a competitive advantage for the future. Although their customers in general do not demand such performance today, nor are willing to pay extra, the added value is expected to win future contracts. The automotive supplier industry on the other hand stated clearly that they indeed were *reactive* when it comes to product level sustainability issues. They did not expect to change their current performance, strategies, or goals unless demanded by the customer or by governmental requirements.

Differences in product level *sustainability strategies and goals* may also account for the difference in total number of information elements ranked as important, independent of stakeholder domain. The furniture industry ranked 19 more information elements than did the automotive suppliers. An important factor in this respect may be internal knowledge and awareness on sustainability issues. Based on the interviews and following discussions in the case firms, the furniture industry appeared to be more *knowledgeable on sustainability issues* in general. This knowledge level may be linked to traditions for sustainability improvements of products. Firm C for instance, is known to be an environmental pioneer within its field, and has worked on product level environmental improvements for several decades. Firm C is also the firm which ranked most information elements as important compared to the other three case firms.

Finally, an interesting issue to address is which stakeholders and what SI the industries consider not to be of importance to product development and design, and why. SI from financial institutions (banks and insurance firms), were considered unimportant by all firms. In addition, most SI from the shareholder domain was considered unimportant. During the interviews, however, both industry sectors underlined the importance of SI to firm brand and reputation, as the firms do not want to be associated with partners, shareholders, or banking connections that have questionable sustainability performance or reputation. Hence, such SI was considered to be of indirect importance to product development and design and was suggested to be more important to the management level in the four firms.

Both industry sectors also found information elements on community development or philanthropy activities, internal population shifts, or direct and indirect employment in developing countries (e.g. the ethics in business decisions regarding second and third world countries) unimportant to product development and design. Several interviewees emphasized that on a personal level, they considered such SI to be important. In a professional context, however, such SI was ranked with low importance as these information elements were considered to be outside the scope of current *firm strategies and goals*. These findings correspond to those of a study on priorities for corporate social responsibility in which community, human rights, and philanthropy issues were all ranked among the least important (Welford et al. 2008).

Figure 1 summarizes all factors suggested to influence the importance ranking of sustainability information relevant to product development and design in the four case firms.

Figure 1 Factors suggested influencing sustainability information *importance* in firms

4.2 Discussions: sustainability information accessibility

Easy access to important SI is a key to building knowledge on sustainability issues in product development and design, which again is important for knowledged-based decisions to be made. Above all, accessibility is a practical problem which can be solved once the factors which influence perceived SI accessibility in firms have been identified. The most significant differences on how accessible important SI is, relates to the stakeholder groups industry associations, suppliers, and customers.

All four firms reported to engage in *information generating activities* with stakeholders, i.e. activities that make SI more accessible, through for instance, participation in various industry associations. Firms C and D reported to have a much more active role in such organizations relevant to their fields than firm A and B did. As firm D put it: "*Being leading within our industry, we have an obligation to share information and help other firms improve their environmental standards"*. Hence, these meeting places become platforms for information sharing between firms within the same industry, and simultaneously provide for the opportunity of early sustainability information acquisition. Firm A and B being less involved in industry associations, may explain the current difference in accessibility rating.

Engaging in research projects and collaborating with academia, are yet other ways of making SI more accessible to firms. All four firms acknowledged the importance of information generated from such activities, but emphasized at the same time the need for academia to make relevant SI more accessible and understandable, i.e. more attractive, through activities like workshops. Reading academic articles searching to gather SI is not regarded as practical or appropriate by the firms. Instead, firms want simplified and easy accessible SI. The potential for mutual learning, knowledge, and practice exchange between firms and academia has previously been reported in literature (Roy and Thérin 2008, Verganti 2008, Erlandsson and Tillman 2009).

In general, the automotive suppliers find customer SI more accessible than do the furniture firms. *Dissimilar customers* may explain this difference. In the automotive industry, "loose" partnerships and close collaboration between the car markers (customers) and the suppliers are common. Collaboration activities make all types of information, including SI, more accessible to the firms. The furniture industry on the contrary, is more detached from its customers. Instead of having 5-10 professional customers, the furniture industry has thousands of individual customers. Hence, collecting SI from these will require more effort to make the SI accessible.

In the supplier domain, the industries rated different information elements as accessible, and the furniture firms also found less SI accessible than did the automotive suppliers. *Different relative strength* between the firms and their supplies may be one factor accounting for this difference. The furniture industry reported to have a large number of suppliers for raw materials and parts, and also to be a small customer for many of its suppliers. Interviewees in firm C and D reported on occasions in which SI had been requested from suppliers, but had not been given as they were not regarded important enough in terms of sales. Firm A and B on the other hand, have few, but large suppliers for raw material. Consequently, firm A and B are regarded as more important by their suppliers, and their suppliers are then more willing to share SI.

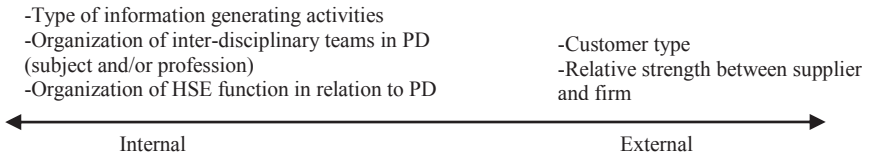
On firm level, an interesting difference concerns *the way product development projects are organized* in the firms, and the types of competence that make up the

projects. All four firms reported that development projects are run inter-disciplinary with respect to subjects, i.e. competence on e.g. construction, computation, design, CAD, material selection, marketing and sales, production, and purchasing etc. (1 ref. removed for anonymous review). What differs between the firms is the professions that hold these competences. Product development projects in the automotive supplier industry are predominantly staffed by engineers in all functions. Being engineers, they are professionally trained to view the world through the same glasses. In the furniture industry, a greater variety of professions are represented like engineers, product designers, ergonomists, physiotherapists, furniture upholsterer, and textile designers. Having different professional trainings and backgrounds, they are likely to search for information in different ways, to attach different importance to different information elements, and to understand information differently (Nonaka 1994, González-Benito and González-Benito 2008). Hence, from an information perspective, it is likely that an inter-disciplinary group, in terms of both subjects *and* professions, may be more successful in identifying, collecting, and sharing SI.

In the case studies, firm C identified significantly more information to be easy accessible than did firm A, B, and D. One possible factor which may explain this difference is how the firms have *organized the in-house HSE/environmental manager functions* internally. In firm C, the environmental manger is organized within the product development department. Being integrated in the product development department, and also physically situated next to product designers, the environmental manger in firm C can continuously feed SI to product designers and engineers and thus make SI easily accessible. All interviewees in firm C also acknowledged that forwarding relevant SI was one of the most important tasks of this function, but also to inspire and push more sustainable solutions in product development, like the "champion" function reported in literature (Johansson and Magnusson 2006).

In the other three firms, however, the HSE/environmental manager function was both physically and institutionally organized outside the product development department. In these firms, this function was typically not directly involved in product development at all (Firm A and B), or only to some extent (Firm D). In the automotive supplier industry, HSE managers are mostly concerned with process HSE issues like exposure to hazardous chemicals in manufacturing, or keeping current processes within discharge limits. The automotive suppliers emphasized, however, that the HSE manager possibly could have relevant SI that currently was neither made accessible nor used in product development. Figure 2 summarizes factors suggested to influence SI accessibility in the firms.

Figure 2 Factors suggested influencing sustainability information *accessibility* in firms



5 Conclusion

In product development and design processes, extensive amounts of information are used. It is therefore important to single out the information elements on sustainability issues that are truly useful to build knowledge. Increased sustainability knowledge in product development and design may be a key to increasing firms' ability and opportunity to develop and manufacture more sustainable products. Sustainable products may be one way of adding value to products beyond functionality, quality, and cost, and thus increase firms' competitiveness.

This article has through four case studies explored such sustainability information grounded in stakeholder theory beyond mere product and process data. Based on product developers' own priorities, the information elements considered most important to product development and design have been identified by combining the results from each industry sector. The sustainability information introduced in the present article may be used in the early phases of product development and design for developing requirements and specifications, and in all development phases as general decision support for continuous sustainability improvements on existing products. Another intriguing area of application for sustainability information is envisioned when such information is used to build knowledge on future scenarios. Sustainability knowledge on future scenarios, trends, and evolutions may inspire firms to propose entirely new meanings to products through sustainability. Verganti (Verganti 2009) has argued that such radical innovation of product meanings are rarely pulled by users, but are instead proposed by firms through design driven innovation by manufacturers' knowledge on future socio-cultural evolutions. Hence, firms' interaction with various stakeholders to gather sustainability information may generate knowledge that may inspire such new product meanings.

Factors influencing sustainability information importance in the case firms may be business strategies, priorities, and goals, sustainability leader vs. sustainability follower, sustainability knowledge and awareness, sustainability standards adherence, in addition to previous positive experience with sustainability information. The wide variety of factors influencing importance rating indicate that sustainability information frameworks as presented here for the furniture and automotive supplier industry respectively should be customized in line with current situations and demands in each firm or industry.

Accessibility of sustainability information was also assessed in the case studies, as well as factors suggested to influence accessibility. Customer type, relative strength between suppliers and firms, type of stakeholder generating activities, types of inter-disciplinary teams, as well as organization of the HSE functions in relation to product development and design, may be factors influencing perceived accessibility of such information in firms. As accessibility of information elements is considered a practical issue, accessibility can be improved by implementing measures affecting these influencing factors in the firms.

Besides the practical implications of these case studies described, this article may have an academic value by adding to the limited body of knowledge on information issues in relation to sustainable product development and design. The studies also add to the organizational aspects and the soft side of sustainable product development, by presenting factors influencing sustainability information importance and accessibility.

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References

Andersen, B. and Fagerhaug, T. (2002) Performance Measurement Explained. Designing and Implementing Your State-of-the-Art System, ASQ Press, Milwaukee.

Aschehoug, S. and C. Boks. 2010. Sustainability Information in Product Development - the Case of Automotive Supplier Industry. APMS 2010, *Internation Conferance on Advances in Production Management Systems*, Cernobbio, Italy.

Aschehoug, S., C. Boks, and S. Storen. 2009. A framework for identification of environmental information among stakeholders. *EcoDesign 2009 - 6th International Symposium on Environmental Conscious Design and Inverse Manufacturing*, Sapporo, Japan.

Aschehoug, S. H. and C. Boks. 2012. Towards a framework for sustainability information in product development. *International Journal of Sustainable Engineering*:1-15.

Aschehoug, S. H., C. Boks, and S. Støren. 2012. Environmental information from stakeholders supporting product development. *Journal of Cleaner Production* **31**:1-13.

Baumann, H., Boons, F. and Bragd, A.(2002). 'Mapping the green product development field: engineering, policy and business perspectives'. *Journal of Cleaner Production*, Vol. 10**,** No.5, pp. 409-425.

Boks, C. and Stevels, A. (2003). 'Theory and practice of environmental benchmarking in a major consumer electronics company'. *Benchmarking - An International Journal*, Vol.10**,** No.10, pp.120-135.

Bos-Brouwers, H. E. J. (2009).'Corporate sustainability and innovation in SMEs: evidence of themes and activities in practice'. *Business Strategy and the Environment.* [online]. Available at: http://dx.doi.org/10.1002/bse.652.

Brown, H. S., De Jong, M. and Levy, D. L. (2009). 'Building institutions based on information disclosure: lessons from GRI's sustainability reporting'. *Journal of Cleaner Production*, Vol.17**,** No.6, pp. 571-580.

Carlson, R., Erixon, M., Forsberg, P. and Pålsson, A. C. (2001).'System for integrated business environmental information management'. *Advances in Environmental Research,* Vol.5, No.4, pp. 369-375.

Charter, M. and Tischner, U. (2001). Sustainable solutions: developing products and services for the future, Greenleaf Publishing Ltd., Sheffield, United Kingdom.

Court, A. W. (1995). *Modelling and classification of information for engineering and design*, Unpublished, University of Bath, United Kingdom.

Donaldson, T. and Preston, L. E. (1995). 'The Stakeholder Theory of the Corporation: Concepts, Evidence, and Implications'. *The Academy of Management Review*, Vol.20**,** No.1, pp. 65-91.

Elkington, J. (1998). *Cannibals with Forks - The Triple Bottum Line of 21st Century Business,* New Society Publishers, Canada.

Epstein, M. J. (2008). *Making sustainability work - Best Practices in Managing and Measuring Corporate Social, Evironmental and Economic Impacts*, Greenleaf Publishing Ltd., United Kingdom.

Erlandsson, J. and Tillman, A.-M. (2009). 'Analysing influencing factors of corporate environmental information collection, management and communication'. *Journal of Cleaner Production*, Vol.17**,** No.9, pp. 800-810.

Forza, C. and Salvador, F. (2001).'Information flows for high-performance manufacturing'. *International Journal of Production Economics*, Vol.70**,** No.1, pp. 21-36.

Foster, C. and Green, K. (2000). 'Greening the innovation process'. *Business Strategy and the Environment*, Vol. 9**,** No.5, pp. 287.

Freeman, R. E. (1984). *Strategic Management: A stakeholder approach*, Pitman Publishing Company, Boston, USA.

Frieder, J. B. (2002). 'Using Information: A Financial Stakeholders' Perspective'. *Corporate Environmental Strategy*, Vol.9**,** No.4, pp. 375-378.

Frysinger, S. P. (2001).' An integrated environmental information system (IEIS) for corporate environmental management'. *Advances in Environmental Research*, Vol.5**,** No.4, pp. 361-367.

González-benito, J. and González-benito, Ó. (2008).'A study of determinant factors of stakeholder environmental pressure perceived by industrial companies'. *Business Strategy and the Environment.* [online]. Available at: http://dx.doi.org/10.1002/bse.631.

Hartono, E., Li, X., Na, K.-S. and Simpson, J. T. (2010). 'The role of the quality of shared information in interorganizational systems use'. *International Journal of Information Management*, Vol.30**,** No.5, pp. 399-407.

Hicks, B. J., Culley, S. J., Allen, R. D. and Mullineux, G. (2002). 'A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design', *International Journal of Information Management*, Vol.22**,** No.4, pp. 263-280.

Hubka, V., Andersen, M. M. and Eder, W. E. (1988). *Practical studies in systematic design*, Butterworth &Co, United Kingdom.

Johansson, G. and Magnusson, T. (2006). 'Organising for environmental considerations in complex product development projects: implications from introducing a "Green" sub-project'. *Journal of Cleaner Production*, Vol.14**,** No.15-16, pp.1368-1376.

Karlsson, C. (2009). Researching Operations Management, Taylor & Francis, New York, USA.

Kong, N., Salzmann, O., Steger, U. and Ionescu-Somers, A. (2002). 'Moving Business/Industry Towards Sustainable Consumption: The Role of NGOs'. *European Management Journal*, Vol.20**,** No.2, pp.109-127.

Larsen, L. B. (2000). 'Strategic implication of environmental reporting'. *Corporate Environmental Strategy*, Vol.7**,** No.3, pp. 276-287.

Lee, Y. W., Strong, D. M., Kahn, B. K. and Wang, R. Y. (2002). 'AIMQ: a methodology for information quality assessment'. *Information & Management*, Vol.40**,** No.2, pp.133-146.

Line, M., Hawley, H. and Krut, R. (2002). 'The Development of Global Environmental and Social Reporting'. *Corporate Environmental Strategy*, Vol.9, No.1, pp. 69-78.

Maxwell, D. and Van Der Vorst, R. (2003). 'Developing sustainable products and services'. *Journal of Cleaner Production*, Vol.11**,** No.8, pp.883-895.

Mcmurtrie, T. (2005). 'Factors influencing the publication of social performance information: an Australian case study'. *Corporate Social Responsibility and Environmental Management*, Vol.12**,** No.3, 129-143.

Moffat, A. and Auer, A. (2006). 'Corporate Environmental Innovation (CEI): a government initiative to support corporate sustainability leadership'. *Journal of Cleaner Production*, Vol.14**,** No.6-7, pp. 589-600.

Nonaka, I. (1994). 'A Dynamic Theory of Organizational Knowledge Creation'. *Organization Science*, Vol.5**,** pp. 14-37.

Prado-lorenzo, J.-M., Gallego-alvarez, I. and Garcia-sanchez, I. M. (2009). 'Stakeholder engagement and corporate social responsibility reporting: the ownership structure effect'. *Corporate Social Responsibility and Environmental Management*, Vol.16**,** No.2, pp. 94-107.

Ringen, G. 2010. *Organizational learning and knowledge in the Norwegian Automotive Supplier Industry*. Unpublished PhD thesis, Norwegian University of Science and Technology.

Roy, M.-J. and Thérin, F. (2008). 'Knowledge acquisition and environmental commitment in SMEs'. *Corporate Social Responsibility and Environmental Management*, Vol.15**,** No.5, pp. 249-259.

Salaün, Y. and Flores, K. (2001). 'Information quality: meeting the needs of the consumer'. *International Journal of Information Management*, Vol.21**,** No.1, pp. 21-37.

Seuring, S. and Müller, M. (2008). 'From a literature review to a conceptual framework for sustainable supply chain management'. *Journal of Cleaner Production*, Vol. 16**,** No.15, pp. 1699-1710.

Tagesson, T., Blank, V., Broberg, P. and Collin, S.-O. (2009). 'What explains the extent and content of social and environmental disclosures on corporate websites: a study of social and environmental reporting in Swedish listed corporations'. *Corporate Social Responsibility and Environmental Management*, Vol.16**,** No.16, pp. 352-364.

Uotila, T. and Melkas, H. (2007). 'Quality of data, information and knowledge in regional foresight processes'. *Futures*, Vol.39**,** No.9, pp. 1117-1130.

Verganti, R. (2008). 'Design, Meanings, and Radical Innovation: A Metamodel and a Research Agenda'. *The Journal of Product Innovation Management*, Vol.25**,** pp. 436-456.

Verganti, R. (2009). *Design-driven innovation. Changing the rules of competition by radically innovating what things mean*, Harvard Business Press. Boston, USA.

Waage, S. A., Geiser, K., Irwin, F., Weissman, A. B., Bertolucci, M. D., Fisk, P., Basile, G., Cowan, S., Cauley, H. and Mcpherson, A. (2005). 'Fitting together the building blocks for sustainability: a revised model for integrating ecological, social, and financial factors into business decision-making'. *Journal of Cleaner Production*, Vol.13**,** No.12, pp. 1145-1163.

Welford, R., Chan, C. and Man, M. (2008). 'Priorities for corporate social responsibility: a survey of businesses and their stakeholders'. *Corporate Social Responsibility and Environmental Management*, Vol.15**,** No.1, pp.52-62.

Yin, R. K. 2009. *Case Study Research*, Design and Methods, Sage Publications Inc., London, United Kingdom.