MANAGING CONCEPT DECISION MAKING
IN PRODUCT DEVELOPMENT PRACTICE

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Managing concept decision making in product development practice

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“The real voyage of discovery consists not in seeking new landscapes but in having new eyes”

*Marcel Proust*
Preface

The journey of being a doctoral student, who finally hands in the thesis, is an amazing experience. Not only have I been able to really study a phenomenon that fascinates me, but also it enabled me to cross my path with several people and organizations, to whom I am very grateful.

My Professor Margareta Norell Bergendahl, with her great impetus, to whom nothing is impossible, always shows a great enthusiasm and encouragement. A huge thank you to my supervisors Sofia Ritzén and Jenny Janhager Stier who have succeeded in balancing the tasks of fostering, supporting and challenging me as a research student in an excellent way. Thanks also to all other colleagues, current and former, at Integrated Product Development at KTH, for thoughtful discussions and an inspiring environment. Further, it has been a benefit for me to be a member of the PIEp network, and especially the PIEp Research School, taking part in the PIEp activities. Thanks also to Professor Larry Leifer who welcomed me as visiting researcher to the Center of Design Research at Stanford University – the time at CDR and Stanford is unforgettable.

I am grateful to my organization at Volvo Car Corporation for believing in me, and opening up the possibility to conduct doctoral studies within the frames of VIPP, the Volvo Industrial PhD Program. The research subject itself, concept decision making in product development, interested me long before I started the doctoral studies due to my own experiences of challenges in product development work. There are of course various ways of approaching these challenges – research is one of them. Therefore, I am grateful for that the company showed an interest for improving its operations and allowed me to scrutinize the own organization “the research way”. Above all, this would not have been possible at all without Bengt Höök and Mikael Fermér, who were indispensable in the process of initiating this research project. Further, my Industrial supervisor Peter Nyström, and my former and current managers Lars-Eric Olsson and Stefan Johansson-Tingström deserve a great thank you for their way to support me and my project along the way: always encouraging, always curious, always helpful. In addition, the members of the Reference Group: Karin André, Monica Gustafson, Hans Lindh, Inger Lundgren, Mårten Levenstam, Sofia, Jenny, Bengt, Peter, Lars-Eric and Stefan, have provided valuable, and crucial input. I have really enjoyed the discussions during these meetings. I would also like to mention all other colleagues at Volvo Car Corporation, with whom I have had several discussions in meetings, at the desk, at lunch, and in the corridors. I have always been met by encouragement, and a willingness to share – and to improve.

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Ingrid Kihlander
Making concept decisions is a crucial activity for product-developing companies since these decisions have high impact on the subsequent development and launch of the products. Consequences of unsuccessful concept decisions can be severe, e.g. missing out on business opportunities or spending money on rework. Concept decisions are experienced as difficult to manage due to the fuzziness of the conceptual solutions and the scarce information available in these early development stages. This thesis investigates concept decision making in product development practice and contributes by enhancing the understanding of what is actually happening, the difficulties experienced in the process, and how to manage and improve concept decision making. Such enhanced understanding should serve as a basis when support methods for concept decision making are developed. In-depth studies have been conducted in a Swedish automotive company, focusing on the technical system level of the product.

The concept decision process was found to be a web of interconnected activities, embedded in the concept development process, and with several actors on different hierarchical levels. Exploration of the concept decision-making process enabled identification of a number of dependence factors influencing the process. An overarching challenge identified in concept decision making was to achieve compatibility before completeness, meaning that compatibility between product systems must be met before the system solutions are completely developed. In addition, a number of conflicts intrinsic in the process were revealed, pointing to underlying causes of the difficulties in managing concept decision making. These conflicts are omnipresent due to the product and organizational complexity and have to be handled by the product developers in their daily work.

The thesis identifies key elements for improving an organization’s concept decision making: Create meta-knowledge and awareness regarding what influences the process and the actors in the process since there is a general lack of knowledge regarding one’s own and the organization’s decision-making processes; Ask questions to ensure that aspects, previously neglected, are considered; Provide visualizations to enhance understanding of both process and solutions; Provide vision as guidance in everyday decision making and trade-offs; and Ensure reflections since there is a need for actors in the process to reflect on the own decision-making process.

In conclusion, a model to improve the concept decision making in practice is proposed. The model includes a set of proposed activities that are designed to address the identified difficulties, and was developed in collaboration between researchers and practitioners.

Key words: concept decision, decision making, product development, industrial practice
List of Appended Papers

Paper A

Paper B

Paper C

Paper D
Kihlander, I. and Ritzén, S. (2011) Compatibility before completeness – identifying intrinsic conflicts in concept decision making for technical systems (Submitted for journal publication, 3rd round of review).

Paper E

Paper F
List of Additional Publications


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INTRODUCTION

1 Introduction

For product-developing companies, their capability of being innovative is a matter of great importance and survival (Brown and Eisenhardt, 1995; Wheelwright and Clark, 1992). Making concept decisions, in the sense of selecting the right ideas and solutions for further development, is a critical and difficult activity in product development and innovation (Khurana and Rosenthal, 1998; Martinsuo and Poskela, 2011; Sharma, 1999).

The success of product innovation is rooted in the early phases of product development (Hauser et al., 2006; McNally and Schmidt, 2009). Several significant decisions are found in the concept development phase, directing the rest of the development and launch work (Kim and Wilemon, 2002; King and Sivaloganathan, 1999; Krishnan and Ulrich, 2001), where also the main part of the product and lifecycle cost is committed (Ulrich and Pearson 1993; Ullman, 1997).

Consequences of unsuccessful concept decisions can be severe for product-developing companies. A company may try to launch the “wrong” products, which may result in poor market reception (Marks, 1989). Sheer design flaws may cause damage to the customers, which in turn forces the company to compensate the customers for pain and suffering (Gries, 2007). Additionally, rework may be initiated, meaning that extra engineering hours have to be spent, and perhaps extra capital investments in new tooling must be made (Carlile, 2004; Verganti, 1997). These working hours and investments are resources that could have been spent on developing new innovative products instead of correcting consequences from previous bad decisions. Therefore, it is of great interest for product developing companies to improve their concept decision making.

Established product developing companies often have internally defined operational support, such as structured development processes prescribing how the work should be performed (Barczak et al., 2009). Prevailing in industry is that these support methods are built upon a rationalistic perspective, recommending the use of structured approaches for selecting what concepts to develop further (e.g. Ulrich and Eppinger, 2008). In line with this, literature encompasses numerous suggestions of support methods regarding evaluation and selection of concept solutions (e.g. Pugh, 1990; Saaty, 1990).

Despite having this operational support, companies suffer from a certain amount of rework. This means spending considerable amounts of engineering capacity and tooling costs on adjusting previous work (Dostaler, 2010; Terwiesch and Loch, 1999), where the cost for changes increases substantially for each succeeding phase in the design process (Clark and Fujimoto, 1991). However, economic figures for such failures (such as rework) are something that companies are reluctant to report externally, and perhaps they are even considered as confidential information.

As a consequence of the uncertain and abstract nature of the product concepts to be judged, it is possible to heavily influence the solutions early in the process, while still having little knowledge about the design problems. This implies that crucial decisions
have to be based on a very uncertain foundation. This can, of course, be experienced somewhat differently in different product development contexts and has been schematically illustrated as the ‘design process paradox’ by Ullman (1997) (Figure 1.1).

![Figure 1.1: The Design Process Paradox (Ullman, 1997)](image)

Thus, concept decisions seem hard to succeed with, and the support used in current practice appears to be insufficient. Why is that so? Making decisions in product development and design is challenging. This is a consequence of the nature of design itself, dealing with various interconnected problems, spanning over several areas and different stages of designing (Jupp et al., 2009). Making decisions regarding concepts also involves balancing risks and opportunities. This balance is challenging to achieve since the knowledge present in early phases of product development is limited, the context is unstable, and the available information may be insufficient (Legardeur et al., 2010; Verganti, 1997). This, together with the observed rework in product development projects, indicates that operational support solely based on rationality does not seem to be enough, given the complexity of organizational decision making in fuzzy concept development phases. Therefore the mutual dependence between concept decision-making practice and related support methods deserves to be investigated further.

The need for research on decision making within product development, engineering design and innovation, incorporating ideas from behavioral and cognitive research on human judgment and decision making has been recognized several times in previous research (Andersson, 2003; Dwarakanath and Wallace, 1995; Hauser et al., 2006; McNally and Schmidt, 2009). This highlights the need for further research regarding concept decision making, and development of suitable support for those activities (Legardeur et al. 2010). Therefore, this doctoral thesis will address the process of making concept decisions, and how to support it in a better way than by the prevalent methods in current industrial practice.

### 1.1 Purpose of thesis

Based on the problems described above, one can conclude that more knowledge regarding concept decision making is needed. Such enhanced understanding and knowledge is a necessity to develop improved support for concept decision making – which addresses the problems not taken care of in the operational support used today.

Hence, this thesis has investigated concept decision making in industrial practice. Concept decisions in these studies have been used in the sense of decisions in early stages of innovation and product development, regarding technical solutions to be developed.
The overarching purpose has been to explore the complex task of making concept decisions in practice in order to gain more in-depth knowledge regarding how it actually proceeds, and what the underlying causes of the experienced difficulties are. The aim is to contribute to theory and practice, as well as to find ways that lead to improving industrial practice, addressing the situation of making decisions in fuzzy concept development phases.

The work has addressed development of complex products in large established companies, and a case company in the automotive industry has been the empirical setting. Large product-developing organizations have to divide their tasks and utilize specialized work forces that belong to different engineering departments, where the operative work strongly influences the concept decisions made. Gerwin and Barrowman (2002) state that research in integrated product development should devote more effort to considering the challenges in complex organizations, e.g. a hierarchy of teams working on a project. This thesis, therefore, uses a perspective of the operative department level of the case organization, aiming to capture the specific challenges that face an engineering department doing development work in parallel with other engineering departments within the same company.

This research aims to strengthen the knowledge and understanding of decision making within product development and engineering design, and contribute to improving product development process management.

1.2 Context of thesis

The research project has been conducted at the Division of Integrated Product Development at KTH, the Royal Institute of Technology, in Stockholm, Sweden. The research at the Division of Integrated Product Development (IPD) addresses organizational and technical processes for efficient and effective development of innovative technology oriented products, services and systems. The research at IPD is performed in close cooperation with industrial companies dealing with knowledge intensive products.

The research project has been carried out as an Industrial PhD project in the Research and Development organization of Volvo Car Corporation, within the Volvo Industrial PhD Program, VIPP. The main part of the empirical studies has been conducted within the company. This has offered in-depth access to empirical data and a possibility for unique insights, as well as continuous verification of the industrial relevance of the research findings.

The project has also been a part of the Product Innovation Engineering program, PIEp (www.piep.se). PIEp is a Swedish research and development program for increased innovation capabilities in organizations, financed by VINNOVA, the Swedish Governmental Agency for Innovation Systems.

1.3 Outline of thesis

The outline of the thesis is as follows. In the Introduction a background and motivation for the research are given together with the purpose of the research project. After the introductory chapter, related theories, such as product development and decision making, are presented in the Theoretical Framework, in order to frame the research project – and to
provide the basis on which the research questions are derived. In the Research Setting and Methodology the research approach and case context, the methods used, and detailed descriptions of the included empirical studies are described. The Summary of Appended Papers presents each paper included in the thesis, regarding its purpose as well as the contribution of the paper to the overall thesis. The results are then reviewed in the Discussion, addressing the characteristics and challenges identified in concept decision making, as well as presenting a model for organizations regarding how they can improve their concept decision making. Finally, in Conclusions, the inferences drawn are presented and followed by suggestions of areas for further research.
2 Theoretical Framework

This research has its starting point in product development, but will also draw on decision-making theory in order to understand concept decision making in product development. In organizational and individual decision making, it is found that people and organizations do not act as rationally as the prevalent methods within product development assume (e.g. March, 1997). Therefore, there is a need to incorporate a broader perspective of decision-making theory in order to gain a wider understanding of the studied phenomenon: actual decision making in concept development. This wider understanding of decision making is needed to achieve the purpose of this research project, i.e. to explore concept decision making in product development practice, since the support methods for concept decision making available at this point have been found insufficient to fulfill the needs in practice.

The theoretical framework will give an overview of the scientific areas related to the research conducted within the frames of this thesis. The main interest of this thesis is the intersection between concept selection within product development, and organizational and individual decision making (Figure 2.1). The chapter starts in the predominant perspective of management of product development processes, and continues with focusing on support methods for concept evaluation and selection. The next section will present related research on how decisions are made, considering both organizational and individual decision making, since focusing on rational methods results in a rather limited picture. Finally, the research questions of the thesis are derived and presented.

![Figure 2.1: Visualizing the focus area of the thesis – Concept Decision Making](image)

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1 The literature search has been conducted throughout the project and has been a combination of different approaches. Databases have been used to search for articles and journal titles that include relevant key words such as concept development, decision making and innovation. Further, journals within the areas of engineering design, product development and innovation management have been browsed. Finally, snowballing has been utilized, i.e. tracing relevant references from publications read.
2.1 Management of product development processes

Product development is “…a set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product” (Ulrich and Eppinger, 2008, p.2), and is the context for the research presented in this thesis. There are several different models of the product development process suggested, and they in general present a sequence of phases. It commences with an initial need (a design problem) and the product is developed and verified to satisfy this need, including phases such as: Planning, Concept Development, Detail Development and Industrialization (Pahl and Beitz, 1996; Roozenburg and Eekels, 1995; Ullman, 1997; Ulrich and Eppinger, 2008). An example can be found in Figure 2.2 where Ulrich and Eppinger’s (2008) generic development process is shown.

The product development process is often treated as a rationalistic flow of activities, where the predominant way to lead and control product development operations is to see them as a rational stepwise process with specific decision points (e.g. Cooper, 2001), emphasizing that decisions are central elements in product development management.

Integrated Product Development is a managerial approach where parallel development activities and cross-functional teams contribute to more efficient product development (Andreasen and Hein, 1987). This approach shows that product development consists of many activities (using several different competences) that have to be planned and correlated, and that several types of competence are needed even in early development phases.

2.1.1 Early phases of product development

A concept is an essential expression in this research. It is defined as an approximate description of the technology, working principles, and form of a product (Ulrich and Eppinger, 2008), where a combination of customer benefits and the technologies needed to embody them is described (PDMA, 2005). Concept development is an early phase in product development (see Figure 2.2). In concept development, concepts should be developed far enough to be able to evaluate the physical principles that govern their behavior and to ensure that the proposed product will operate as expected and that, with reasonable further development, it will meet the defined targets (Ullman, 1997). Hansen and Andreasen (2002), however, call attention to the fact that a good concept has consequences in three dimensions: a profitable business; a good product; and a manageable product development process. Further, they assert that a concept has a dual
nature, and can be seen from both a need/market-oriented, and a design/realization-oriented, perspective. Therefore the understanding of concepts should include both the idea with and the idea in the concept (Hansen and Andreasen, 2002).

In the extensive literature covering concept development, many definitions and expressions are used to describe the process, such as concept development, generation, evaluation, selection, screening, scoring, comparing and eliminating. Despite the variety of wording, concept development is generally described as follows: generate a number of concept solutions, evaluate the alternative solutions, and finally select one or a number of concept(s) to develop further in the detailed development stages (Krishnan and Ulrich, 2001; Pahl and Beitz, 1996; Pugh, 1990; Roozenburg and Eekels, 1995; Ullman, 1997; Ulrich and Eppinger, 2008). In Figure 2.3, Ulrich and Eppinger’s (2008) overview of the front-end activities is shown as an example. In this respect, concept development includes both generation of concepts (enlarging the solution area) and evaluation of concepts (narrowing the solution area) – where this thesis focuses on the latter, converging part. Concept decisions can therefore be seen as intermediate, and at the same time crucial and pivotal, steps in innovation and product development processes.

![Figure 2.3: Front-end activities in concept development (Ulrich and Eppinger, 2008)](Figure 2.3)

In most cases the literature treats one concept (e.g. VDI, 1986) to be developed in detail, but sometimes it uses a saving clause stating that concept selection should perhaps end up with “one (or more)” selected concept(s). Interestingly, there has actually been a change during the years in Ulrich and Eppinger’s (2008) overview of the front-end activities (Figure 2.3), where the figure has been updated: “Select a Product Concept” (up to 2nd ed.) is replaced with “Select Product Concept(s)” (from 3rd ed.).

Toyota’s successful approach of set-based concurrent engineering (Morgan and Liker, 2006; Sobek et al., 1999; Ward et al., 1995) has been reported as an alternative to the point-based strategy. This literature asserts that Toyota’s designers think about sets of design alternatives, which are found within a solution space that continuously decreases, rather than pursuing one alternative iteratively. This approach aims to avoid iterations and eliminate work on solutions that later must be changed (Ward et al., 1995). Further, it is reported that Toyota’s engineers and managers try to delay decisions and provide their suppliers with difficult specifications very late in the project (Ward et al., 1995). For instance, Toyota’s General Manager of Body Engineering states that “The manager’s job is to prevent decisions from being made too quickly… but once a decision is made, we change it only if absolutely necessary” (Morgan and Liker, 2006, p.39).
2.1.2 Fuzzy front end

Early phases of product development are important for the success of product innovation (Hauser et al., 2006; McNally and Schmidt, 2009), which was mentioned in the introduction of the thesis as one of the starting points for this research project. Innovation can, however, be considered both as a process and as an outcome (Crossan and Apaydin, 2010). According to the PDMA Handbook (2005) the innovation process may be divided into three areas: the Fuzzy Front End (FFE); the New Product Development (NPD); and Commercialization. The FFE encompasses activities preceding the more formal and well-structured NPD process (such as the one described in Figure 2.2). The FFE is often chaotic, ill-defined, and unpredictable (McCarthy et al., 2006), characterized by conflicting organizational pressures, ad-hoc decision making, and unstable contexts (Khurana and Rosenthal, 1998; Legardeur et al., 2010; Montoya-Weiss and O’Driscoll, 2000).

To address these challenges, several approaches are suggested. Khurana and Rosenthal (1997; 1998) assert that it is important to have a systems perspective, and a holistic view, integrating business strategy, product strategy, and product-specific decisions. Further, Kim and Wilemon (2002) emphasize the need for understanding of the FFE including the sources of FFE ambiguity, and organizational support and encouragement for the FFE activities. This can be addressed by the common terminology suggested by Koen et al. (2001) in order to provide clarity of the FFE. There are also different proposals addressing how ideas should be evaluated in early stages, such as developing a holistic but informal assessment system (Martinsuo and Poskela, 2011; Montoya-Weiss and O’Driscoll, 2000). However, it is pointed out that one should not be tempted to use the same approach for all cases (Koen et al., 2001; Reinertsen, 1999).

In empirical studies it has been found that concept development can include not only the concept stage in the product development process, but also the preceding activities, such as the ‘pre-program planning phase’, i.e. covering activities in both the unstructured Fuzzy Front End and the more structured product development (Backman et al., 2007; Setterberg, 2008). This has implications for this thesis since it highlights a need to make the empirical studies in an open manner, even if the research mainly focuses on the concept development phase.

2.1.3 To foster innovation

Omnipresent challenges in the management of innovation are for example a structural problem of managing part-whole relationships, but also how to sort out the right ideas and manage them through the whole process from idea to product (Sharma, 1999; van de Ven, 1986), pointing to the importance of making good decisions. Further, to foster innovation in an organization, several aspects regarding the climate and culture in the organization should be considered.

Leaders should stimulate openness, and also promote information sharing and integrated thinking (Hammedi et al., 2011; Khurana and Rosenthal, 1998). Moreover, the management should communicate with co-workers, encourage them, and pay attention to them in order to bring meaning to the work done (Menzel et al., 2007), as the example from Honda illustrates: the concept development team knew that its success strongly depended on the support from the executives (Meyer, 2008). Further, clear goals to which the co-workers can commit themselves have been found to have positive effects...
(Santa et al., 2011), and there are even examples of technology-forcing regulations that have been found to drive innovation (Lee et al., 2010).

A company should also strive for having an open culture and climate in the organization (Ekvall, 1996; Nicholson, 1998; van Riel et al., 2004), fostering an entrepreneurial environment in the organization where risk-taking and experimentation should be encouraged (Buckler and Zien, 1996; Cooper and Kleinschmidt, 1995; Johne and Snelson, 1988). It is suggested that innovation managers ‘go with the flow’ because, even if they cannot control the flow, they can learn to maneuver through the innovation journey (Crossan and Apaydin, 2010) by using reflexivity, since this is found to have a positive effect on efficiency in early stages (Hammendedi et al., 2011).

Further, flat hierarchies, low-level centralization, and reduction of bureaucracy are found to increase the likelihood of innovation (Johne and Snelson, 1998; Menzel et al., 2007). To achieve innovation in large firms, it is required to have enough resources in terms of people, time and room for maneuvering (Menzel et al., 2007), and to avoid letting the bureaucracy in the company suppress both creativity to generate new ideas and the initiatives to transform them into businesses (Sharma, 1999).

2.1.4 Strengths and challenges of support methods in product development

For product development there are several types of support available: computer systems such as PDM (Product Data Management) for handling all product data; or CAD (Computer Aided Engineering) for modeling the geometry, but also support processes, models and methods for product development such as concept evaluation methods. In literature, the use of design methods is suggested in order to improve product development work, and a large number of structured support models and methods (both at overall level and on a more detailed level) are proposed (e.g. Pugh, 1990; Ulrich and Eppinger, 2008).

Regarding the overall level and how to model the product development process, there are several suggestions (see Figure 2.2 for an example), and Taylor (1993) states that the fact that there is no one model is a sign of how complex product development is. However, several models are very similar, and this is named by Roozenburg and Cross (1991) as the consensus model. This model consists of sequenced phases and intermediate gates, similar to Cooper’s Stage-Gate Model® (Cooper, 2001), and constitutes a backbone regarding internal instructions used in many product-developing companies (Barczak et al., 2009; Engwall, 2003b). Models like these have been, according to Roozenburg and Cross (1991), developed within engineering design since the 1960s. The consensus model is based on a number of assumptions, such as: (i) decisions gradually become more detailed; (ii) knowledge of the solutions is raised during the project; and (iii) solutions evolve from being general and abstract to being particular and concrete (Engwall, 2003b; Roozenburg and Cross, 1991). The overall problem can be broken down into distinct sub-problems and sub-sub-problems. Sub-solutions are developed and then ‘synthesized’ into an overall solution (Roozenburg and Cross, 1991). Models and methods are understood and used in different ways: each actor interprets them according to the actor’s own perspectives, context, and daily practice (Christiansen and Varnes, 2009; Engwall et al., 2005). In addition, management influence can change a system from being a possible checklist into mandatory requirements and vice versa (Christiansen and Varnes, 2009).
There are several empirical findings that show gaps between what literature prescribes and what is found in empirical studies (Christiansen and Varnes, 2009; Roozenburg and Cross, 1991). For instance, it has been observed that step-oriented design methodologies are rarely followed by designers (Stempfle and Badke-Schaub, 2002). This corresponds to the discrepancy between what theory-of-action people espouse and what they actually use, i.e. how individuals describe their actions versus what actually governs the actions (Argyris and Schön, 1974; Brown and Duguid, 1991). Therefore it is of great interest to look into what companies state regarding how they should work, but also how they actually work since it is the actual practices that determine the success or failure of organizations (Brown and Duguid, 1991). This motivates further empirical studies, since the industry has the rational step-sequenced processes as internal instructions, while at the same time several studies have shown these models’ shortcomings.

When studying prescriptive models available in literature (on product development in general and concept development in particular) the product development process is depicted as a rational and stepwise process on an overview level. However, in the text provided close to the model it is often commented that the processes are iterative. For instance, in Roozenburg and Eekels’ (1995) model there is a feedback loop from the decision step to both analysis and synthesis in the basic design cycle. Cyclical iterations between generation and evaluation are shown in several models (Pugh, 1990; Ullman, 1997; Ulrich and Eppinger, 2008). Additional concept generation and refinement can be initiated (Ulrich and Eppinger, 2008), and should be performed whenever necessary (Pahl and Beitz, 1996). In VDI 2221 (1986) an assumption is made that the different steps have been worked through iteratively before deciding the final solution. Roozenburg and Eekels (1995, pp.23-24) summarize that “…in product development everything has to do with everything and everything proceeds into everything…” Thus, iterations are necessary but hard to visualize in the overview models, which have implications for development of any support process models.

A stage-gate model has benefits such as being easy to understand, enabling control, and creating confidence, according to Engwall et al. (2005). The gradual and formalized decision process serves the purpose of disciplining co-workers and preventing insufficient solution proposals from being realized, since a project can be terminated, or changed rather extensively, in the gate events during the process (Engwall, 2003b). These support models and methods can be strong management tools in organizations (Engwall, 2003a), since they are considered as encouraging integration, coordination and communication (Cross, 2000; Engwall et al., 2005; Norell, 1992; Ulrich and Eppinger, 2008). More recently, a transition away from prescriptive design process models into more descriptive, context-aware models has occurred in the design methodology literature (Kopecka et al., 2011). This new generation of models emphasizes the integration of different design functions (both internal and external), the need for reflection as a means of learning, and that a designer most often works in a teamwork environment (Kopecka et al., 2011).

On the more operative level, structured methods also serve to ensure that important issues are remembered, educate new product developers, clarify decision bases, reduce unconfirmed decisions, and document decisions for future reference (Ulrich and Eppinger, 2008). On the individual level, structured methods and procedures can help the designer to make a systematic search for solutions in a wide field and think of other
solutions than the first one that appears (Eder, 1998). The methods will also support the
designers in transferring their thinking onto paper, possibly through diagrams and charts
– i.e. externalizing the design thinking, which frees cognitive resources for intuitive and
imaginative thinking (Cross, 2000).

In engineering design literature it is agreed that structured methods for evaluation of
solutions are preferable in the concept development process. In fact, companies that used
formal methods were considered to be more successful (Barczak et al., 2009), even if they
were not fully satisfied with the methods for concept selection that they were using
(Salonen and Perttula, 2005). Structured selection methods can be used to reach a
controlled convergence (Pugh, 1990), since the methods provide a more rational (using
objective criteria) and transparent procedure, which decreases personal bias (Andersson,
2003; Cross, 2000; Ulrich and Eppinger, 2008).

Despite the wealth of methods and tools proposed to help structure the concept
selection process, utilization of support methods has not been highly developed. An
investigation in Swedish industry showed that 30% of the companies responding in the
survey used an evaluation method at some point, and only 15% of the companies replied
that they used evaluation methods on a regular basis (Janhager et al., 2002). Similar
observations of a low degree of utilization of support methods in the concept phase are
also reported in other studies (Araujo and Benedetto-Neto, 1996; Gustavsson and
Sterner, 2008; Salonen and Perttula, 2005). For instance, less than 25% of the companies
that responded in Salonen and Perttula’s (2005) study used one or several of the formal
methods included in the study: Pugh’s evaluation matrix, Rating matrices, or Analytic
Hierarchy Process (AHP). However, there are a number of support methods that are
wide spread, even though there seem to be some differences in what methods being
popular in what country (Fujita and Matsuo, 2005).

In elaborations on the low degree of utilization of systematic design methods in industrial
practice, several explanations have been put forward. Many methodologies require large
quantities of data which are either unavailable or difficult to obtain (Frost, 1999). Hein
(1994) emphasized the need-driven practice, which entails that what is used is a
combination of current practice and modern buzzwords rather than an in-depth
knowledge of available theoretical methods. Perhaps the languages differ between
industry and academia and the methods are used, adjusted to the company, and not under
their academic names (Frost, 1999). Engineers might neither be trained to use methods,
nor have the time to learn new methods (López-Mesa and Bylund, 2011). Further,
experienced designers are able to develop good solutions early in the design process
without employing methodological strategies or doing systematic analysis of important
information, and might not interested in “how it should be done” (Frost, 1999; von der
Weth, 1999). Some researchers state that methods are used (Matthiasen, 2011; López-
Mesa and Bylund, 2011), and most interesting are the reports regarding the use of the
more pragmatic, and within-company developed methods for design reviews and concept
selection (López-Mesa and Bylund, 2011; Salonen and Perttula, 2005).

Structured step-sequenced models of product development processes have been
criticized for being designed neither to handle a changing environment, nor to support
knowledge enhancement during the development project, since these models assume that
all relevant knowledge is available from the start of the project (Engwall, 2003a;
Ottosson, 1996). Therefore, these models have been found to support innovation projects insufficiently since knowledge regarding possible solutions has to be created as the project is run (Engwall, 2003b).

A certain flexibility has been called for when adapting such rules to specific situations (Christiansen and Varnes, 2009; Cooper, 2008; Tatikonda and Rosenthal, 2000). Support methods should therefore be designed in a way that raises the likelihood of implementation and utilization of the methods. Norell (1992) asserted that the methods should: be easy to learn, understand and use; incorporate accepted, non-trivial knowledge within the focused area; and be developed for use by several professions and thereby contribute to creating a common frame of reference. Support methods should also, according to Pahl and Beitz (1996), reduce hard workload, save time, prevent human error, foster inventiveness and understanding, and help to maintain an active interest. Furthermore, the way the support methods are implemented has been identified as crucial for success (Eder, 1998; Norell, 1992; Beskow and Ritzén, 2002). An explicit example of how important it is for industry that a method is easy to learn, and is available, are the interview answers from a technical executive, reported in Killander (2001): “Can my engineers use it with less than two days training?” and “Is the methodology supported by a software tool that can be used by every engineer?” Therefore, Geis et al. (2008) have proposed a model for implementation of method into daily practice, which is based on four pillars:

* Simplification of methods (most methods are still too theoretical for practical use).
* Adaptation of methods (methods are often designed to support designers in specific situations, not fitting into the daily routines).
* Promotion of methods (methods must be prepared for change, and further a culture positive towards methods should be established).
* Development and implementation of appropriate training of design methods (designers do not spontaneously start using methods, methods have to be taught at appropriate events).

There can, however, be unintended consequences when using support methods. For instances, internal supporting documents have been found to indirectly influence the process (Christiansen and Varnes, 2007). Different types of templates could be identified as boundary objects that transfer, translate and transform knowledge across functions (Carlile, 2004). Christiansen and Varnes (2007) found when studying gate meetings that the templates used became obligatory passage points in the process. This had the result that the power was displaced from the meeting into the templates, since the information gathering prior to the gate meeting became a signal of what the management considered to be important (Christiansen and Varnes, 2007). With this as a background, the following section will focus on available support for evaluation and selection of concept solutions.

### 2.2 Evaluation and selection of concept solutions

The traditional approach to concept selection stipulates that the concept is frozen before the detailed product design starts (Krishnan and Ulrich, 2001). However, selection of a conceptual design is more dynamic in nature than most other decision-making problems (Yeo et al., 2004), facing the challenge of both complexity and uncertainty (Olausson and Berggren, 2010). At the same time, selecting the right ideas and concepts for product
development projects is among the major decisions that product development managers must make (Martinsuo and Poskela, 2011; Okudan and Tauhid, 2008; Sharma, 1999).

Ideally, a designer should know enough about each concept, in order to choose an alternative to concentrate the resources on for the further development (Ullman, 1997). However, in early project phases, information about the product concepts is insufficient; thus concept decisions are made using qualitative information, judgments and incomplete evaluations (Blessing, 1994; Chin and Wong, 1999; Ullman, 1997), where the uncertainty can have several aspects such as imprecision, inconsistency, inaccuracy, indecision, and instability (Wynn et al., 2011). Jönsson (2004) concluded that decisions in early phases of product development are preliminary, being of a “what-if” type. Further, he used a “tent” metaphor to describe this kind of situation: decisions seem to serve as “tent pegs” in setting up the total result (i.e. a tent). Eventually contradictions occur and the “tent pegs” have to be adjusted in order to get an acceptable overall result. Further, the information-sharing process might be obstructed by designers who are found to lack confidence in handing out preliminary information to colleagues, because they are afraid of being wrong (Badke-Schaub and Frankenberger, 1999).

In addition, criteria for evaluation used in these early phases lack clarity compared to later stages where more explicit criteria could be defined (McCarthy et al., 2006; Schmidt et al., 2009; Yang, 2010). Due to the fuzziness and uncertainty, there is a risk that the product developer wants to quickly advance into the detailed development where more firm information will emerge (Verganti, 1997). Therefore, a problem according to Verganti (1997) is how to encourage uncertain information to be gathered in the early phases, without entering into detailed design.

When investigating decision making in the front end of discontinuous innovations Reid and de Brentani (2004) identified three critical interfaces: boundary, gate-keeping and project. The boundary interface involves an information flow inward from the environment to the individual, and the gate-keeping interface is an information flow inward from a gate-keeping individual into the organization. Both these interfaces are on the individual level, yet the individuals play different roles in the two interfaces. The project interface is an information flow from the organization to a specific project, which is being considered during the first screening, and where the decisions usually are made by senior managers at the organizational level. This shows that decision making happens in many different shapes, with different actors involved. This has implications when designing the gathering of empirical data in this research work, thus rendering it important to try capturing a complete picture.

2.2.1 Support methods for evaluation and selection of concepts

Concept evaluation methods are designed with the assumption that different alternatives are generated, and that the methods will be used for evaluating these alternatives, thereby identifying the best one(s). However, empirical findings show quite another picture and it is reported that often only one or a few alternatives are generated (Blessing, 1994; Chin and Wong, 1999) and that little time is spent on discussing the importance of different evaluation criteria (Girod et al., 2003).

There are numerous support methods for evaluation and selection of concepts available, and some of the most usual will be referred to below. Selection of concept(s) can be done
in several (more or less structured) ways, and it could be said that even if only one concept is generated the team is using a method: choosing the first concept they think of (Ulrich and Eppinger, 2008). Examples of other methods for concept selection that may be used are: the decision is handed over to the customer (external decision), an influential team member makes the decision (product champion), or by intuition (‘gut feeling’) (Ulman, 1997; Ulrich and Eppinger, 2008). Evaluation methods may or may not include a decision rule, meaning that the method establishes the ‘best’ alternative or perhaps just supports assessment of the overall value of the alternatives – i.e. not supporting the decision maker in the last step of the process (Roozenburg and Eekels, 1995). How to make the specific concept decision is seldom explicitly elaborated in engineering design literature but rather seems to be included in the concept selection. Hence, a decision is mostly seen as an obvious result of a concept evaluation, even if Avigad and Moshaiov (2009) point out that concept selection means the filtering of concepts in a rational way, and not necessarily the making of a final concept selection.

Analytical approaches for concept evaluation are a specific research strand. For instance, Gandy et al. (2006) demonstrated how to use expert information and Monte Carlo simulations. Based on the Analytical Hierarchy Process (AHP) proposed by Saaty (1990), Ayag and Özdemir (2009) recommended the Analytical Network Process (ANP) as decision support for concept evaluation. In the AHP and the ANP, the decision situation (including goals, attributes and stakeholders) is modeled as a hierarchy (AHP) or a network (ANP) to provide an overall view of the relationships in the decision situation. Ayag and Özdemir (2009), nevertheless, note that the risk of decision-maker bias towards any particular alternative cannot be ruled out while applying these models.

Even though a variety of evaluation methods have been proposed by the authors of textbooks on engineering design, many authors are quite united in recommending the use of a decision matrix. They recommend an evaluation performed in a team, where a number of alternatives are evaluated, using a number of criteria, against a reference solution (Cross, 2000; Pahl and Beitz, 1996; Pugh, 1990; Roozenburg and Eekels, 1995; Ullman, 1997; Ulrich and Eppinger, 2008). There are different sorts of decision matrix methods but they mainly include the following steps: identify criteria for evaluation, possibly weighting the criteria; select alternatives to be compared; generate scores; and compute a score. A well-known example is Pugh’s evaluation matrix (Pugh, 1990), where different alternative solutions are compared to chosen reference and then rated better (+) worse (-), or the same (S) on each chosen (non-weighted) criteria. However, concept selection methods have been criticized for neither providing traceability (Ng, 2006), nor treating coupled decisions in a proper way, pointing to a shortfall since most real-world problems include a great many interconnections (Dwarakanath and Wallace, 1995; King and Sivaloganathan, 1999; Okudan and Tauhid, 2008).

Several authors have reviewed and compared different selection methods (Andersson, 2003; Baker and Albaum, 1986; Frey et al., 2009; Katsikopoulos, 2009; King and Sivaloganathan, 1999; Okudan and Tauhid, 2008; Otto, 1995; Ullman, 1997; Weiss and Hari, 1997; Yeo et al., 2004). They have investigated different methods regarding e.g. ease of use, cognitive effort required, treatment of multiple attributes, weighting of different attributes, and handling of coupled decisions. Summarizing these overviews is not as straightforward as one could hope, since the different reviews used different patterns for labeling the methods. For example Pugh’s evaluation matrix has been labeled in the
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different overviews as: relative (Ullman, 1997), graphical (King and Sivaloganathan, 1999), or equal weight heuristic (Andersson, 2003). However, a number of general conclusions can be drawn:

- Most methods can handle multiple attributes (King and Sivaloganathan, 1999).
- To reach an effective evaluation, alternatives and criteria for evaluation should be in the same language, have the same level of abstraction (Ullman, 1997), be deduced from the product specifications, and be agreed (Pugh, 1990).
- Pugh’s selection matrix was considered to be the method most easy to understand and to use (Weiss and Hari, 1997; King and Sivaloganathan, 1999; Salonen and Perttula, 2005), although Salonen and Perttula (2005) stated that simplicity has its price since Pugh’s method considers neither the importance of different criteria, nor any difference in magnitude. The AHP was found to be more complex and time-consuming, which might cause a loss of concentration as the number of comparisons goes up (Salonen and Perttula, 2005; Yeo et al., 2004). The QFD-matrix (Quality Function Deployment) was considered to have the greatest clarity due to its graphical template (King and Sivaloganathan, 1999).
- For unbiased and honest concept selection, Weiss and Hari (1997) recommend Pugh’s evaluation method, but when biases are present in the team they instead recommend a semi-quantitative, sophisticated selection procedure. As soon as any kind of weighting is included there is also an element of bias present (Yeo et al., 2004). Addressing this, the pair-wise comparisons in the AHP are said to reduce the effect of decision-maker bias (Salonen and Perttula, 2005). Therefore, King and Sivaloganathan (1999) assert that Pugh’s method is suitable for the task of eliminating highly unfeasible concepts.
- When adding a new alternative the AHP requires a new set of pair-wise comparisons, and besides the problem of lengthy computations, a drastic changing of the order of preferences may occur, such that it no longer resembles the original ranking (Yeo et al., 2004).
- Methods such as the Pugh process leads to higher-quality designs that are produced with less cost and are delivered more quickly than the designs chosen by methods using weighting-and-rating (Katsikopoulos, 2009). Further, the Pugh method outperformed the rating-and-weighting method when creativity was modeled as part of the design decision process while the two methods were equally profitable when there was no creativity (Frey et al., 2009). There are also other examples where the fast and frugal methods matched or outperformed the competitors regarding speed and accuracy (Gigerenzer and Goldstein, 1996). Katsikopoulos (2009) therefore concludes that the Pugh process fosters creativity while other methods stifle it.
- When two or more concepts are found to be close, Weiss and Hari (1997) state that the intuition of the project manager will be the best selection tool.
- Weiss and Hari (1997) and Baker and Albaum (1986) concluded that the selection method has to be adapted to the circumstances, such as the type of product involved, the nature of the company, its existing product line, markets and goals.

In addition to the overviews and comparisons presented in literature there are several researchers who have presented methods that they consider as addressing needs that are not taken care of by the current evaluation methods. For instance, Avigad et al. (2011) have developed a computational tool that takes aspects of supply chains into account, including suppliers’ related uncertainties. Further, Justel et al. (2007) have presented a
method that supports companies in assessing the innovation potential of product concepts, taking into account the degree of novelty of product concepts and their potential for success in the market. This is in line with what Martinsuo and Poskela (2011) assert: managers should not only pay attention to the immediate product, but also include the long-term strategic opportunities when evaluating the ideas and concepts. However, using too formal assessment might create hindrance in the early phases of product development (Hammidi et al., 2011; Martinsuo and Poskela, 2011).

Regarding research and development of support methods for concept evaluation, there is an ongoing debate within engineering design regarding what is most important: method rigor, aiming for coherence (scientism); or method applicability, aiming for correspondence (praxis) (Reich, 2010). For coherence the criterion is internal (logical consistency), and for correspondence the criterion is external (success in the real world); and while criteria of logic are domain-independent, criteria of correspondence depend on the decision problem (Katsikopoulos, 2009). Hazelrigg (2010) strongly advocates the scientism side and claims that only methods which are mathematically proven to work are valid for design decisions. Hazelrigg (2010) is quite sharp in his critique of the more heuristic approaches based on Arrow’s impossibility theorem. The theorem says, in short, that individual preference orders can not be summarized into a group’s preference order (Arrow, 1950). Reich (2010) defines these opposing views as advocating method coherence (scientism) or method correspondence (praxis), but he also concludes that their positions do not really contradict each other – they actually address different things.

2.2.2 Unanticipated factors affecting concept evaluation and selection

The section above gives an overview of available support methods for concept evaluation and selection, showing a couple of examples of the large quantity of available methods. However, in spite of all these available methods, empirical findings have shown how decision making on concepts has been influenced by unanticipated factors. For instance, designers might get fixated on or attached to a certain solution principle and tend to stick to this principle for as long as possible (Blessing, 1994; Cross, 2006; Jansson and Smith, 1991; Purcell and Gero, 1996). This could affect the conceptual design negatively if it prevents the designer from considering all the relevant knowledge that should be taken into account, or if the designer will hold on to a certain solution for too long. The origin and driver of the concepts (e.g. technology or market) can also affect how the different concepts are supported from different parts of an organization, according to Backman et al. (2007). For instance, they found that a technology-driven concept received more support in a technical organization. Further, the way a concept is presented, and individuals’ valuations of different attributes, as well as team members’ knowledge and understanding of the different concept alternatives, seem to influence the judgments. Low knowledge of the concepts can entail that evaluations may be based on other information than presented in the concept description (Hambrick et al., 2005; Lera, 1981; Reidenbach and Grimes, 1984), and in empirical tests it happened that respondents said that they understood the concept when, in fact, they did not (Reidenbach and Grimes, 1984).

In the studied industry (automotive) the appearance of the product (the car) plays a major role. Therefore, it is interesting that what the product’s form communicates might overrule objective information, and consumers naturally incorporate what the form
communicates into judgments of feature performance (Hoegg and Alba, 2011). Being exposed to the product several times may also influence how a certain product concept is judged (Coughlan and Mashman, 1999). Further, the important elements of product design may cause challenges for global marketing, since “things that seem obvious in one market may be completely different in another market”, which was illustrated by the fact that the color pink is considered to be masculine in Japan, yet more feminine in North America (Townsend et al., 2010, p.57).

Concluding this section, it can be stated that decisions regarding concept solutions do not follow a rational stepwise process, highlighting that existing support methods are not sufficient for actual concept decision making. Therefore, the author has chosen to include literature regarding organizational and individual decision making in this research, based on an assumption that taking this wider perspective will contribute to the management of concept decision making.

2.3 Making decisions

“Decision making is like talking prose – people do it all the time, knowingly or unknowingly” (Kahneman and Tversky, 2000, p.1). It is only through their decision making that people can purposely exercise any control over their situation (Keeney, 2004). It is important to make good decisions simply because we care about the consequences of our decisions and naturally prefer good consequences to bad consequences (Keeney, 2004).

In the academic world, research on decision making is performed within several scientific disciplines. It spans from rational mathematics and optimization to psychology, cognition, human behavior, and covers descriptive, prescriptive and normative models of decision making. Normative decision science describes how decision makers should make choices, when given ideal conditions, while descriptive decision science focuses how people actually make decisions (Brown and Vari, 1992; Luce and von Winterfeldt, 1994; Riabacke, 2007). Prescriptive decision science, in contrast to both descriptive and normative, treats development of applicable decision aids, i.e. aids that can be effectively used given the inherent challenges of being a human decision maker (Brown and Vari, 1992; Luce and von Winterfeldt, 1994). After the introduction in this section, literature related to that decisions seems to be made in a process is presented. Further, previous descriptive research regarding both organizational decision making and individual decision making will also be presented. This knowledge has been used when designing the empirical studies in this research project, being aware of the complexity that occurs in actual decision making.

A decision is an irrevocable allocation of resources – irrevocable in the sense that it is impossible or extremely costly to change the situation back to what existed before making the decision (Howard, 1966). Another definition is that a decision is the commitment to an action whose aim is to produce satisfying outcomes, whereas decision making is the process of solving a particular type of problem (Yates, 2001, p.17). In the area of Decision Analysis, Howard (1966) makes a strong distinction between a good decision and a good outcome. A good decision is a logical decision based on uncertainties, values, and preferences of the decision maker, while a good outcome is what one wishes to happen. Howard (1966) further states that decisions and outcomes are related, since the possibility of reaching good outcomes increases if the decisions made are always good.
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Classical rational decision making (meaning when decision making is striving for maximum utility, not considering the effort and cost of doing the information search) requires a complete information search, and is based on the following prerequisites, as summarized by March (1997):

* Knowledge of alternatives: decision makers have a set of alternatives for action.
* Knowledge of consequences: decision makers know the consequences of alternative actions.
* Consistent preference ordering: decision makers have consistent values, which are used in comparisons of consequences of alternative actions.
* Decision rules: decision makers have decision rules that are used to select a single alternative of action on the basis of its consequences for the preferences.

Analytical tools have been developed in order to support decision making in areas such as Multi Criteria Decision Making. For example, Saaty (1990) developed the Analytical Hierarchy Process (AHP) where the goals, attributes, issues and stakeholders are arranged in a hierarchical manner in order to visualize the complex relationships in the decision situation, and to help the decision maker make comparisons through giving the issues different orders of magnitude. Further, computer-based tools have been developed in the area of decision support and decision aid, referred to as Decision Support Systems (DSS). However, the use of analytical tools for decision making is not very extensive (Riabacke, 2006). These analytical tools are mostly based on normative rules where the value of a tool is completely dependent on the quality of the input data, concerning both probabilities and utilities (Riabacke, 2007). Therefore, Jupp et al. (2009) argues that tools for technical analysis and optimization of decisions cannot meet all different dimensions of dynamic decision processes, since no single approach is sufficient to handle the richness and variety of possible decision situations and process behaviors.

Linking decision making to product development, McCarthy et al. (2006) have identified three levels of decisions: strategic, review, and in-stage. At the highest strategic level, decisions relate to market and product strategies, and project portfolio management. The second level of decisions occurs between stages in the product development process, reviewing the status of the project: whether the stage is completed and if the project should proceed or be terminated. Finally, the third level of decisions relates to decisions made at the operational level, and is by McCarthy et al. (2006) called in-stage decisions. At the in-stage decision level, agents deal with multiple decisions that involve producing and processing a rich diversity of rules and criteria that are the basis of creative activities and ideas in the product development process (McCarthy et al., 2006). This research project mainly focuses on the two lower levels: review and in-stage decisions, and in the following next decision making will be treated from a process perspective, before both organizational and individual decision making are presented.

2.3.1 Decisions growing out of a process
Based on empirical studies of decision-making processes, Nutt (1984) stated that nothing in his empirical findings remotely resembled the normative methods described in literature. This has also been noted when studying decision making in product development. Rather few ‘rational’ decisions have been observed (Christiansen and Varnes, 2006), teams shift between planned and unplanned activities (Cross and Clayborn Cross, 1995), and decisions made are hardly results from applying methods for finding an
optimum solution (Beheshti, 1993). In descriptive research on decision making in product development, there are many examples from both early and more recent research, showing a wide gap between the normative, linear and sequential perspectives and empirical results (Bessant and McMahon, 1979; Christiansen and Varnes, 2007; Dwarakanath and Wallace, 1995; Hansen and Andreasen, 2004).

In his empirical studies, Nutt (1984) identified five types of decision-making processes: the historical model, the off-the-shelf, the appraisal, the search, and the nova process types. They all began with formulation and ended with implementation. However, the processes differed in their approach to idea generation and process-management rationale. Most decision processes were found to be solution-oriented, which seemed to restrict innovation, and to limit the number of alternatives considered. For example, the nova process was the only process type with activity in the conceptualization stage aiming to find new innovative solutions (Nutt, 1984). However, the nova process was only observed in 15% of the cases studied, and executives were found to prefer copying ideas of others, or searching for ready-made solutions instead of seeking innovation.

In product development, decisions seem to be growing out of a process over time instead of being made at a specific moment in time by one explicit decision maker (Christiaans, 2010; Hansen and Andreasen, 2004; Wickelgren, 2005). Further, Dwarakanath and Wallace (1995) observed, in their studies in product development, two main types of decision-making processes. The first type corresponds to the evaluation methods available in the literature, meaning that several alternatives were generated, and then evaluated in parallel against defined criteria. In the second type, an alternative was evaluated as, and when, it was generated. After the alternative was evaluated, it was either modified or a new alternative was generated, showing a strongly coupled process of generation and evaluation (Dwarakanath and Wallace, 1995). The iterative, not necessarily stepwise, connections between evaluation and synthesis have also been observed by Suwa et al. (2000), and it has been concluded that design problem solving is a complex behavioral activity (Beheshti, 1993), where technical, social and cognitive processes of design interact (Cross and Clayborn Cross, 1995). Interestingly, Keeney (2004) comments that he used to think that decision analysis should be made in a step-sequential manner – but now he believes that there should be much more interaction between generation and evaluation to resolve a decision.

A consequence of the ‘multi-faceted’ character of the decision-making process is that it is a challenge even to capture where, and how, decisions are actually made (Bragd, 2002; Christiansen and Varnes, 2007; Jönsson, 2004; Gustavsson and Sterner, 2008). For example, Bragd (2002, p.85) stated, based on her observation studies in a development project: “I cannot say when or how it happened even though I was there. Suddenly, everyone in the project team was aware of the chosen direction”. In the observed processes a variety of iterations and non-linear elements have been identified (Badke-Schaub and Gehrlicher, 2003; Styhre et al., 2010). When studying the design process, Badke-Schaub and Gehrlicher (2003) defined five patterns of decision making in product development, meaning how the progress of reaching a decision looks, involving the different actors:

* Leaps: fragmented process, no clear common goal in the group, and deficient decisions that had to be revised.
* Loops: reiterations, long time period for decision, and poor results.
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- Cycles: reiterations of partial sequences of process steps, long decision process, controlled muddling-through.

Leaps and loops were identified as being less successful than the three step-sequential patterns (cycles, sequences and meta-processes) and should thus be avoided. However, 47% of the observed decisions in the study were identified as belonging to the two less successful patterns (Badke-Schaub and Gehrlicher, 2003).

Wickelgren (2005) studied a project management team and recorded that “actual decisions” were a relatively small and formalized part of the process; instead he emphasized what happened before the decisions. He concluded that a main share of the process was not spent on making decisions, but rather on deliberations regarding issues concerning the decisions to be made later; thus the management team members were acting more often as deliberation makers than decision makers. Bragd (2002) observed that the organization she studied more or less relied on “directions”, “recommendations”, or “tracks”, which organized and structured relevant matters. Within engineering design research the use of tentative decisions, where criteria and information available in each tentative decision situation are used was observed by Hansen and Andreasen (2004). Further, López-Mesa and Chakrabarti (2007) identified implicit decisions during the process, which were results of actions as well as inactions.

Decision making and deliberations seem to be strongly related, if treating deliberations as processes of interpretation and sense-making, addressing ambiguity and conflicting interpretations of organizational situations (Lundqvist, 1994). Pava (1983, p.59) defines deliberations as: “patterns of exchange and communication in which people engage with themselves or others to reduce equivocality of a problematic issue” and cover all communication and reflection regarding a specific topic. This also includes value-adding interactions that occur outside the formal organizational structure and between meetings, which differs from a discrete decision or project milestone in that it encompasses informal human interactions and information related to a particular topic over time (Purser, 1992).

It has been noted earlier that meetings in product development organizations are not usually used as decision points (Bragd, 2002; Christiansen and Varnes, 2006; Christiansen and Varnes, 2007). Instead Bragd (2002) found that the meetings were used for screening the status and keeping the pace in the project and not for decision making. Christiansen and Varnes (2006) observed that the gate meeting became an arena for justifications of the decisions already made, and that the gate system and the gate meetings became a signal and symbol of rational behavior. Further, Schmidt et al. (2009) detected, when studying project reviews, that more criteria were used in incremental than radical projects, and more technical criteria were used in incremental projects, while more financial criteria were used in radical projects.

Face-to-face is identified as the richest medium for communication, and such meetings are considered to support mutual understanding and agreement, and thereby have an ability to overcome differences. It allows immediate feedback, through communication channels such as body language and tone of voice, and a natural language is used to express the message content (Daft and Lengel, 1986). However, an identified challenge is to create forums for deliberations that relate important details to the whole system and
vice versa when the organizations consist of highly specialized labor (Lundqvist, 1994), and the fact that it is hard to fit such deliberation into tight meeting schedules since the few minutes allowed in the agenda do not provide a good basis for sense-making (Jönsson, 2004). It has also been observed that interactions in the meetings, e.g. who was presenting the issue, affected judgment of the content, meaning that if the person was trusted in the organization the possibility to obtain the required decision was higher (Jönsson, 2004). Further, Bragd (2002) observed that the project leader, instead of listening to every detail of what was presented, listened to the “rhythm of the project”, meaning how project members presented different issues instead of just paying attention to what was presented.

To describe the non-linear decision-making process, Lindblom (1959) used the term ‘muddling through’, which meant successive limited comparisons and approximations to some desired objective, in which what is desired itself continues to change. To judge whether an outcome is satisfying, Lindblom stated that there often are no preferences and a “good” policy is when there is an agreement that it is a good policy. Gradually, decision makers develop a definition of the situation which is workable for them. Kopecka et al. (2011) point out that design activity does contain the same core elements as the above-described ‘muddling through’ process. March (1997) continues that decision making is a process of matching the decision situations and the decision maker’s identity, reflecting what is considered to be an image of proper behavior, and hence decision making is more about appropriateness than about logic of consequences.

Product development often experiences a time pressure since time to market is an important factor for success. Having too much time pressure or rigid time constraints may impinge on the process in a negative way. For instance, there is a risk of making premature decisions based on immature problem understanding (Little, 1987), or decreased demand for quality where solutions are accepted despite the knowledge that they are sub-optimal or even wrong (Badke-Schaub and Frankenberger, 1999).

Decision-making processes can be modeled in several different ways, using different perspectives. For example, they can emphasize the information flow, the division of work, or the division of authority (where the organization is the rules of the game) (Koopman and Pool, 1991). Further, there is the garbage can model (Cohen et al., 1972) where an organization consists of choices, problems, issues, decision situations, solutions, and decision makers – more or less randomly mixed. However, in this research work no single model has been used when analyzing the empirical data. Instead the knowledge of the different models has enhanced the inductive analysis, looking at the process with a broad scope including e.g. activities, actors, and support, and therefore, the next section will focus on decision making also from the organizational perspective.

2.3.2 Organizational decision making
The studied context in this research project is work within a product development organization. Therefore, organizational decision making is of great interest. March (1997) points out that classical normative decision theories underestimate the interactive conflicts, confusions and complexity inherent in actual decision situations in organizations. Organizations are open systems including many internal, external and interrelated decisions, many actors, and several events that happen at the same time. This means that decisions may be coupled, possibly affecting each other, but not necessarily
coordinated (March, 1997; Pasmore, 1988). In addition, organizational goals are seldom entirely clear, and are often undergoing changes (Koopman and Pool, 1991). Further, in the complex situations of industrial practice there are different stakeholders, acting as decision makers, both internal and external to the development project, influencing the decision-making process and its result (Hansen and Andreasen, 2004). Inter-departmental collaboration, necessary in product development, has been found to bring both opportunities and hindrance to the decision-making process in innovation (Cuijpers et al., 2011; Troy et al., 2008). For example, Weiss and Hari (1997) reported potential problems of passing the decision through local and higher management.

Many decisions in organizations have both logical and political aspects, and decision making is not a neutral event since it generally takes place in a force field in which different preferences and different definitions of social reality play a role (Eisenhardt and Zbaracki, 1992; Koopman and Pool, 1991). Organizational and social environments where the decision makers act will determine the consequences they will anticipate, and the ones they will not; what alternatives they will consider, and which ones they will ignore (March and Simon, 1958). Little (1990), however, commented that the issue of power has not been treated adequately in the organization literature.

Communication and the availability of information, in an organization influence the decision-making process (Badke-Schaub and Frankenberger, 1999). Communication is much supported by the group characteristics (e.g. group organization, group climate and division of work), but also the novelty of the task, which requires a certain level of coordination and communication (Badke-Schaub and Frankenberger, 1999). To agree, and get buy-in, among the co-workers is found to be a key factor in how team members perceive the decision-making quality (Yang, 2010), even if consensus is often difficult to obtain (Ullman, 1997; Weiss and Hari, 1997).

In the same way as organizational decision making is relevant for this research project, individual decision making is relevant as well, since organizations are inhabited by individuals with their attributes and subjectivities. Therefore, the subsequent text will treat individuals as actors in the organizational decision-making process.

2.3.3 Individual decision making

People are not rational decision makers (Certo et al., 2008), since rational decision making “assumes intellectual capacities and sources of information that men simply do not possess” according to Lindblom (1959, p.80). Due to people’s limited knowledge, ability and capacity of information processing it is stated that humans can be rational only within certain limits (bounded rationality), and that decision makers stop the information search when they find an alternative that is good enough (Simon 1955; 1956). It has also been found that individual preferences are not stable; instead the preferences are contingent on the demands of the task (Bettman et al., 1998; Payne, 1982). Only in exceptional cases are decision makers concerned with discovery and selection of the optimal alternative (March and Simon, 1958). Instead they rather make their decisions based on traditions, rules of thumb, intuition, or “a hunch” that appears to be correct (March, 1997), perhaps affected by psychological traps and biases interfering with the decision making (Gilovich et al., 2006; Hammond et al., 2006; Posavac et al., 2010; Tversky and Kahneman, 1974). For instance, Tversky and Kahneman (1974) identified three heuristics that are employed when making judgments under uncertainty: representativeness, availability, and anchoring.
and adjustment. This means misjudging based on: a sample that is not representative, information that is easy available for the decision maker, or getting influenced by an initial value (an anchorage) when making subsequent judgments.

Correspondingly, Hammond et al. (1998) identified similar challenges for the individual decision maker, and called them the hidden traps in decision making:

- Anchoring trap: give disproportionate weight to the first information received
- Status-quo trap: bias towards maintaining the current situation
- Sunk-cost trap: perpetuate mistakes from the past
- Confirming-evidence trap: seeking out information supporting an existing belief and discounting opposing information
- Framing trap: misstating a problem, undermining the entire decision-making process
- Overconfidence trap: overestimating the accuracy in the forecasts
- Prudence trap: being overcautious when making estimates about uncertain events
- Recallability trap: give undue weight to recent, dramatic events

Keeney (2004) has reflected that many of these psychological traps cannot be avoided. Therefore he recommends being aware of where they are most likely to occur, and minimizing the negative impact of their occurrence. In addition, it is of great value for decision making to have systemic knowledge, meaning a capability to detect early which elements in one’s own decisions may have significant consequences for the subsequent activities (Verganti, 1997). Verganti (1997) continues: systemic learning only occurs if people receive and conceptualize the feedback related to their original choices. In line with this, Argyris (1976) has earlier stated that how decision makers can monitor the effectiveness of their decisions, and the receptivity to corrective feedback, are crucial for the effectiveness of learning. Moreover, it seems that the more important, or threatening, the decision is, the harder it is to provide that feedback, fundamental for learning (Argyris, 1976).

Knowledge can be built up through experience. However, experience can be a double-edged sword. Besides providing good information availability and contextual knowledge (Rehman and Yan, 2011), great experience can lead to ignoring a thoroughly made goal analysis (Badke-Schaub and Frankenberger, 1999), or perhaps some impatience ‘to get on with it’ where experienced people consider that a procedure holds them back from arriving at a solution (Pugh, 1990). Further, the individuals also influence the process. When team members share the same motivational approach, this not only influences new product decisions, but also diminishes or eliminates the influence from the top management (Spanjol et al., 2011).

Design methodology literature treats the design decision-maker(s) as conducting rational discourse on design alternatives (Hansen and Andreasen, 2004). However, making rational choices is beyond the capacity of a designer (Beheshti, 1993). People therefore have to simplify the design problem, and thereby make them cognitively manageable (Posavac et al., 2010), to be able to reach a decision, or else there would be no progression in the design process (Lera, 1981; Roozenburg and Eekels, 1995). In product development there are no right answers, only satisfactory answers, and a certain amount of noise exists (i.e. any factor that you cannot or choose not to control) in real-world decision making (d’Anjou, 2011; Ullman, 2002). Keeney (2004) points out that decision making might involve more of eliminating bad alternatives than selecting the best
alternative. Further, Christiansen and Varnes (2008) conclude, based on their studies of project portfolio meetings, that decisions are rather constructs than calculative outcomes, meaning that it is more a matter of making appropriate decisions than of optimal or rational decision-making.

In individual decision making there are several subjective aspects present. Subjective aspects are critical parts of decisions, since the foundation for decision making is and must be based on subjective information Keeney (2004), and Roozenburg and Eekels (1995) state that most design decisions are made with elements of intuition. Only by combining intuition, logic and emotions can individuals operate at the most effective levels, and confident decision makers use both logic and intuition according to Patton (2003). Further, Zeelenberg et al. (2008) emphasize that emotions help in decision making since emotions are there for a reason – namely for guidance and prioritization. The weakest part of this process is, however, the lack of thinking about the subjective components of the decision, according to Keeney (2004). Stanovich and West (2002) clarified the different ways of making decisions by dividing the action into System 1 and System 2. System 1 refers to a process that is fast, effortless, and intuitive. System 2 is a slow, controlled and rule-governed decision-making process. In order to deal with this duality, there are researchers who claim that they present methods which are based on psychology and sociology combined with rational mathematical methods (e.g. Ahn and Dyckhoff, 1997; Gidel et al., 2005; Montagna, 2011; Sinclair and Ashkanay, 2005; Ullman, 2002).

Nutt (1999) has examined various tactics for decision-making and concluded that some tactics with a good track record are commonly known, but uncommonly used. Therefore, he gives the following advice to managers who would like to improve their decision making:

- Personally manage your own decision-making processes – take charge
- Search for understanding – signals can be symptoms
- Establish your direction with intervention and an objective
- Stress idea creation and implementation
- Identify more than one option
- Deal with barriers to action

Other authors also maintain that there should be different alternatives to choose between when making decisions (e.g. Eisenhardt, 1989a; Roozenburg and Eekels, 1995; Tatum et al., 2003) and Nutt (1999) reported that the success rates jumped from 56 to 70 per cent when multiple options were developed.

Finally, decision making can be considered as a skill according to Keeney (2004), and he emphasizes the importance of the qualitative parts of decision processes, and points out the role of decision analysis as a way of thinking through the decisions. However, very few people have ever had any training in decision making (Keeney, 2004; Riabacke, 2007).

### 2.4 Research questions

Concluding the presented literature, a number of statements can be made that point to a need for further research on concept decision making. First, there are numerous support methods for making concept selection available. However, utilization of support methods...
is found to be low in industry. This might be for several reasons, such as that the needs of industrial operations are not met by the available support methods, or simply bad practice in the companies. Second, decision making on concepts is challenging for both the organizations and individuals involved due to the limited knowledge and insufficient information available early in product development projects. Third, the reviewed literature on decision making in product development shows discrepancies between normative decision-making methodologies suggested in product development to steer decision making in a rationalistic way, and descriptive research findings from empirical studies of product development practice.

Given the research purpose, i.e. to explore and understand concept decision making, and the previous research presented above, the following research questions were defined for the thesis:

RQ1: Given the conditions of high product complexity and uncertainty of early product development phases, which are the difficulties occurring in concept decision making, and how can they be explained?

RQ2: How can the specific difficulties encountered in concept decision making be managed?

In order to answer the research questions, a deepened understanding of the actual process of concept decision making must first be created. Further, underlying causes of the challenges experienced in the concept decision-making process should be explored. Finally, an aim of the research project was also to improve industrial practice. Therefore answering the research questions will enable work with improving concept decision making in practice.


3 Research Setting and Methodology

This chapter provides a presentation of the research approach adopted in the research project. It begins with presenting the setting in which the research project has been conducted. That means discussing the characteristics of an Industrial PhD project and implications thereof, and also presenting the case company. The chapter continues with the way the research has been performed, including a presentation of the Design Research Methodology (DRM) that has been used as a framework, the methods used, and the empirical studies included in the thesis. Finally, what has been done to ensure quality in the conducted research, is presented.

3.1 An Industrial PhD project

The research project has been conducted as an Industrial PhD project. This means that the author is employed in the case company (and is expected to continue the employment in the company after finishing the PhD studies), and is conducting research studies in the own organization. Further, the Industrial PhD is enrolled as a PhD student at a university, having the same academic requirements to fulfill as any other PhD student. Thus, the individual is a member of both academia and industry. Having Industrial PhD students in companies is a phenomenon well known, but scarcely documented, within the Swedish engineering research community (Kihlander et al., 2011). Given the purpose and aim of the project, creating both knowledge and change, and the setting of the research project, there are some implications for the research work, drawing from both insider research and action research. Therefore, this section will discuss both benefits and challenges of studying the own organization as well as when researchers and practitioners work together to generate both knowledge and change.

3.1.1 The case company

This research project was initiated in the case company, which is an automotive company, and consequently it has the automotive industry as the case context. Even though the automotive business has been extensively used as a research context in previous research (e.g. Berggren, 1993; Clark and Fujimoto, 1991; Drucker, 1946; Henderson and Clark, 1990; Morgan and Liker, 2006) some specific characteristics of the automotive industry still deserve to be pointed out. Automotive companies develop and sell cars, i.e. highly complex expensive consumer products, often for a global market where the competition is fierce. The automotive industry is firmly regulated by different authorities at the same time as the market expects new innovative products continuously. Additionally, there are numerous people who could be considered as car enthusiasts, which means that many people are quite opinionated regarding the products, no matter if they are customers or not, where for example the appearance, and the brand of the products are important aspects.

The case company has its headquarters in Sweden, and develops its products for a global market. The main parts of the Research & Development, Marketing, Product Design and
Manufacturing organizations are also situated in Sweden. The products encompass thousands of components that together should provide customer satisfaction in many different areas, such as being a pleasure to drive, having low impact on the environment and being safe. Therefore, the development of cars requires several competences and functions. The Research & Development organization in the case company encompasses around 3500 employees, mainly organized in a number of engineering departments: Powertrain, Chassis, Body & Trim, and Electrical Engineering. There is also a Complete Vehicle Engineering department that acts on the complete vehicle level with a responsibility to integrate and balance the systems into a complete product. Additionally, project managers responsible for early concept phases are organized in the Complete Vehicle Department, while project managers leading the execution phase of the projects are organized in a separate organization, namely Project Management.

The company is employing a matrix organization in the product development work. Having a matrix organization means that both project and functional organizations are involved in the concept decision making, and a number of different meeting forums, in both functional and project organizations, are appointed as decision-making meetings regarding the technical content of the products. Accordingly, various roles and hierarchical levels have been used to sample participants for the studies. The research project has had its main emphasis on a micro level, focusing on the perspective of one of the engineering departments, responsible for developing a part of a car, delivering to all ongoing projects.

The company makes use of a project portfolio, where several development projects are run in parallel. In the portfolio it is very common that projects are strongly related, e.g. through sharing the same platform solutions, which adds further complexity in the development work. A development project in the organization’s portfolio typically runs over a number of years and involves hundreds of people with different competences.

3.1.2 Study your own organization

Studying the organization of which you are a complete member has benefits as well as some inherent risks. Being an insider means having benefits such as pre-understanding the problem and the context as well as access to the organization, while there might be challenges such as reviewing the findings in an objective way. An insider also has the expectation to remain a member of the organization when the research is completed (Brannick and Coghlan, 2007). For instance, the author in some cases was in a position of hierarchical dependence on the respondents. However, the author did not experience this as a hindrance for conducting these interviews in an open way at any time.

It can be questioned whether a person employed in the studied organization really can obtain the objectivity necessary for doing research in the own organization (Anderson et al., 1994; Guide, 2007). Since an insider is a part of the organization’s culture, it may be difficult to stand back from it in order to assess and criticize it (Coghlan and Shani, 2008). A challenge experienced by the author was the risk of being trapped in preconceived opinions of how things are at the company, or how they ought to be, but also having a partial perspective as defined by Coghlan and Shani (2008). Therefore, it is important to be aware of strengths and limits of the pre-understanding, and Brannick and Coghlan (2007) emphasize that the knowledge and experience should be used in a reflexive way to reframe the understanding of situations to which one is close. An insider researcher has
to face the situation of being both an organizational member, and a researcher, which can have consequences of ambiguity and conflicts between the two roles, when having to balance the interests of the researched organization and of science (Brannick and Coghlan, 2007; Coghlan and Shani, 2008; Gummesson, 2000). The organizational role may demand total involvement and active commitment in the organization, while the research role may demand a more distant and reflective position, which can have the result that the insider action researcher begins to feel like an outsider in both roles (Coghlan and Shani, 2008). To reduce such risks for biases and conflicts, actions were taken during the research project. For instance, when selecting respondents for the empirical studies, both purposive and chain-of-referral samplings were used. Additionally, in the collaboration between the author (insider) and outsider researchers (i.e. the supervisors), benefits such as combining the insider’s understanding of, and access to, the studied organization and the outsider’s more objective perspective were sought for. This has been utilized continuously in the process of conducting the empirical studies (e.g. when designing the interview guides), analyzing the research data and drawing conclusions.

Insider research is said to provide important knowledge about what organizations are really like (Brannick and Coghlan, 2007), since it “offers a unique perspective on systems, precisely because it is from the inside” (Coghlan and Shani, 2008, p.644). Ottosson and Björk (2004) agree by stating that working as an insider researcher has been shown to increase usability and trustworthiness of the research findings in product development processes due to continuous data access, enabling insider researchers to grasp what really happens on a daily basis. The closeness offers intimate and continuous communication with actors in the organization, which reduces the risk of misunderstandings (Björk, 2003; Mikaelsson, 2004). The author has also used geographical closeness that made it easy to approach people face-to-face or to attend meetings on short notice. The personal experiences and pre-understanding of the author helped to identify where to probe, meaning where to look and whom to ask, but also in having a knowledge regarding “who’s who and what’s what”, and also how the informal power and information systems works in the company.

When conducting the interviews the author experienced a number of advantages of being an insider. The introductions during the interviews were kept to a minimum, enabling the interview time to be used effectively, e.g. not spending the time on having the respondent explain the organization. Further, the author had the possibility to ask questions using general expressions (from theory) as well as utilizing the specific expressions used within the case company, as a consequence of being a member of both academia and industry. In addition, the author found that the respondents had no intention of “putting up a nice surface” for such an internal interviewer, who could easily check the testimonies given. Besides the access to the organization and the people in it, the author would like to point out the advantage of having access to the company’s document management system, where documents such as instructions or meeting protocols are available.

Finally, discussing the insider perspective, the author’s pre-knowledge of the studied organization should be presented. The author has been employed in the case company and has been working with product development for seven years prior to the doctoral studies. The author has had positions such as being a Change Agent addressing operations on the R&D level, as well as being a Design Task Leader, leading a cross-functional team in a new car project doing hands-on product development work.
3.1.3 Researchers and practitioners collaborating to create knowledge and change

An Industrial PhD project has by nature a strong connection to the case company, since it is grounded in a problem experienced by the company, combined with a scientific issue to be investigated. Inherent in this setting, there is an ambition that new knowledge will be established, as well as resulting in changes in the researched context, within the frames of the research project. Therefore, having this practice-centered aim of the research paved the way for being inspired by action research, and utilizing a collaboration between researchers and practitioners.

Action research is defined as research conducted simultaneously with action in practice, being future-oriented – aiming to create a more desirable future for the researched organization (Susman and Evered, 1978). This means having dual goals: contributing to both science, creating new knowledge, and to the researched organization through supporting change (Gummesson, 2000; Rapoport, 1970). Further, it has been stated that action research also aims to develop self-help action competencies among people facing the problems, i.e. improving their learning (McNiff and Whitehead, 2006; Susman and Evered, 1978). Action research aims at “enabling science” (Susman and Evered, 1978, p.599) and “to make use of science, or to make science useable” (Pålshaugen, 1996, p.151), generating theory that is grounded in action (Susman and Evered, 1978).

When researchers and practitioners collaborate, there is great potential to create knowledge that otherwise would have been hard to discover (Fendt and Kaminska-Labbé, 2011). For example, practitioners might already know how to do things, taking them for granted, but there also might be hidden rationalities (perhaps hidden even from the practitioners themselves) inherent in daily practice (Argyris and Schön, 1996). In this research project, several practitioners have been involved in different roles e.g. as respondents in interviews, as subjects for observations, in verifying research findings, in testing and evaluating the author’s suggestions, in prioritizing issues to be dealt within the research project, and as receivers of research results. Interaction with practitioners has been a part of the project all along, from the definition of the research project to the synthesis of the research findings.

The methodology in such a collaboration is open-ended and developmental (McNiff and Whitehead, 2006), and has to be adapted to the situation (Patton, 2002; Susman and Evered, 1978). Further, one should be aware of the political dynamics (Coghlan and Shani, 2008), since doing research is never neutral, and is done by someone with specific aims and intentions (McNiff and Whitehead, 2000). Change may be threatening to people, and has to be dealt with in a delicate way. The author has considered this, in trying to sense what is possible to suggest as improvements for the case organization, and what might be fruitless to propose for the case organization, in line with the self-awareness and sensitivity that Coughlan and Coghlan (2002) call for.

In addition, a Reference Group was appointed for the research project with the purpose of reviewing and supporting the project and the emerging research results. The Reference Group included a number of individuals appointed due to their experience and positions in the case company, as well as the academic supervisors, the industrial supervisor, and the author’s functional manager in the company. The Reference Group has been informed about the research plans and results, and these sessions have provided fruitful input, comments and insights during the project.
3.2 Design Research Methodology – DRM

The goal of design research is, according to Blessing and Chakrabarti (2009), to make design more effective and efficient in order to enable design practice to develop more successful products. Therefore design research not only aims to create knowledge, but is also assumed to cover implementation of tools and methods that improve design processes in industry. Blessing and Chakrabarti (2009, p.5) define design research as “the development of understanding and the development of support”. Since this is in line with the aim and purpose of the research project, namely developing understanding of and support for concept decision making, the author has chosen the Design Research Methodology (DRM), developed by Blessing and Chakrabarti (2009), as a framework for the research project presented here.

DRM contains the following stages: Research Clarification, Descriptive Study I, Prescriptive Study, and Descriptive Study II (an overview can be found in Figure 3.1). In the Research Clarification stage a realistic and meaningful research goal should be formulated, and an initial literature search should be made, in order to clarify assumptions used when describing the existing and wanted situations. Criteria to be used to evaluate the outcome of the research should be identified initially. The Descriptive Study I (DS-I) aims to increase the understanding of the existing as-is situation, and empirical studies and further literature should be performed in order to understand what is influencing the addressed situation. Factors that have strong influence on success should be identified, and this increased understanding of the existing situation should be used as a basis for the next stage, where support is to be developed. In the Prescriptive Study (PS), support addressing one or more factors in the existing situation is developed. Finally, Descriptive Study II (DS-II) has the purpose of investigating the impact of the developed support and its ability to realize the wanted to-be situation, regarding the support’s applicability as well as its usefulness. Within the DRM framework, iterations between, and parallel execution of, the different stages are encouraged, and a research project may start or end in any stage.

![Figure 3.1: DRM framework: Stages, basic means and deliverables](image-url)
3.3 Methods used for data collection and analysis

The nature of the research questions, together with the origin and expected outcome of the research project, have guided the planning and execution of the research, namely utilizing qualitative methods and mainly inductive analysis of data. In this section the chosen qualitative approach, and methods used for data collection and analysis, will be presented. Further, literature studies have been conducted during the whole project.

3.3.1 Qualitative approach in data collection

Riabacke (2006) points out, based on his experience from research on decision making, that the structure as well as the culture of organizations must be examined, since they both influence the decision-making processes to a great extent. Further, Keeney (2004) emphasizes the benefit of using real decisions, and not laboratory problems, in decision research. Therefore, a qualitative approach was chosen in this research project, since a qualitative research approach is useful when the aim is to explore and to obtain an overview of a complex area of interest (Robson, 2002), and for obtaining insights into individuals’ and groups’ experiences and the meaning attached to these experiences (Leech and Onwuegbuzie, 2007). The qualitative approach is about taking the respondents’ perspectives and grasping their experiences of the investigated situations. Since mind-reading is not an alternative in this research project, qualitative methods such as interviews, observations, and archival search have been used as data collection methods, with the researcher as the primary instrument of investigation.

This research has focused on the concept decision making in one case organization, and there it has conducted a number of empirical studies, influenced by case study design. Case study design focuses on understanding the dynamics present within a single setting, considering that the case is hard to separate from the rich, real-world context (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Yin, 1994). The advantage of going in-depth, however, brings some limitations to the possibilities to make general conclusions (Voss et al., 2002).

The research is primarily based on other people’s testimonies and statements, together with the author’s own interpretations of what was observed. Therefore, the author would like to acknowledge that the empirical data is to a large extent based on individuals and what they apprehend but also what they choose to describe in their testimonies, based on their experiences, ambitions and specific contexts. Miles and Huberman (1994) point out three sources of biases and pitfalls in qualitative research, which the author has tried to mitigate as far as possible: interpreting events as more patterned and congruent than they really are; over-weighting data from articulated, well-informed, usually high-status informants; and losing one’s perspective and being co-opted into the explanations and perceptions of local informants.

*Interviews* were used as the main method, because interviews are efficient for collecting rich empirical data (Eisenhardt and Graebner, 2007). All interviews were made in a semi-structured manner, where the respondents were sampled purposively or by chain-of-referral (Bryman, 2008; Patton, 2002). Since it is important in case-based research to seek out person(s) who are best informed (Voss et al., 2002), the procedure of chain-of-referral is a way to identify information-rich informants (Miles and Huberman, 1994). The semi-structured design allowed the interviewer to modify the order and exact
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wording of the pre-determined questions, and add follow-up questions during the interviews, if that seemed appropriate in order to improve the quality of the interviews (Robson, 2002). The conducted interviews all followed the same framework: introductory questions about the respondent (current role, and history in the company); focus area of the specific interview series; supporting questions; and a summary. In the end the respondents were also given the opportunity to reflect on the subject and add extra comments if they felt something relevant had not been covered by the interview questions. All interviews were conducted in Swedish, digitally recorded, and transcribed by the author. During the interviews there were always blank sheets of paper provided for the respondent to sketch on, which the interviewer brought from the interviews and included in the data to be analyzed.

Observation studies were also included in the research project, following ongoing development work, and decision-making meetings. During the observations field notes were taken, supported by a template developed by the author for this specific purpose. Making observations puts high demands on the researcher since it is required to be highly perceptive, structured and disciplined (Merriam, 1994). The author acted as an observer-as-participant (Gold, 1958), where the author’s role as observer was known by several people being observed, but not all people present in the observed situations. The author aimed to cover what Merriam (1994) recommends: register time, place, participants and citations; listen for key words; register the environment, integration between people, typical situations, atypical situations, informal and unplanned activities, non-verbal messages, and what is not happening. Additionally, the researcher has taken notes regarding the research project all along, since the start of the research project.

Archival search was made as a part of some of the included studies. The author utilized the access to the company’s business management system for instructions, including process maps, forum descriptions, and role descriptions. Protocols and other notes from the meetings observed were also retrieved from the company’s document data base.

Contextual information was also gathered during the whole research project through having an office desk in the organization. Moreover, as a consequence of the fact that the author is employed in the organization, all information distributed internally and reaching the respondents reached the author to the same extent. This kept the author updated on “what was going on” in the organization at the time of each study.

3.3.2 Analysis of empirical data

When analyzing data the first step is to immerse oneself in the case, also known as “soaking and poking”, followed by the analysis guided by the research objective (George and Bennett, 2005). Inductive analysis, which has been applied for most of the analysis, involves discovering themes, patterns, contradictions and categories in the data (Patton, 2002; Voss et al., 2002). As a consequence of own research findings and gaining more knowledge of theory, abductive elements were also used in the analysis in the later part of the research project (Patel and Davidson, 2003). An iterative approach using data reduction, data display, and conclusion drawing/verification (Miles and Huberman, 1994) was employed, letting the findings emerge from the data through the interaction with it, acknowledging the element of intuitive work and subjectivity, i.e. the craftsmanship, in the analysis. The interpretive elements are greatly recognized by the author, since, according to McNiff and Whitehead (2000), a researcher does not leave one set of values
at the door and take up another for the research, in the same way as the knowledge that is generated is socially constructed. The data analysis has been characterized by iterating in a number of dimensions: between text analysis and display of data and between deep dives and overall synthesis. The unit of analysis has been the decision-making process, and it was chosen not to work with pre-defined codes in an attempt to approach the empirical data with as little bias as possible. Instead the strategy was to let themes emerge from the raw data and subsequently identify categories (Kvale, 1997; Leech and Onwuegbuzie, 2007), which is a method of choice when the aim is to answer general, overarching questions about the data (Leech and Onwuegbuzie, 2007).

The analyses in all the studies were made by the author. In several studies the analyses were made in collaboration with an outsider researcher (i.e. a supervisor) utilizing an insider/outsider combination, aiming to triangulate. These analyses were performed iteratively, having a continuous dialogue in the research team, where the degree of independence of the author grew during the research project. In the data analysis Microsoft Office tools were used, such as Word® and Excel®, in order to keep track of all transcribed data as well as the traceability of respondents, roles, and content categories. No matter what computer programs the researcher use for supporting the analysis, Leech and Onwuegbuzie (2007) emphasize that the researcher is still the main tool for analysis, having flexibility, creativity and intuition and can only be assisted, never replaced, by a computer program in performing such analysis.

3.4 Empirical studies

This doctoral thesis is a result of a research project conducted over a number of years. The project included empirical studies that addressed the overall research questions in different ways, in order to strengthen the research findings. An overview of the empirical studies can be seen in Figure 3.2. The studies Spectcase, Compcase, Curr&Fut Study and Dev&Elab Study will be presented in detail below, where the purpose of the studies has moved from understanding to suggesting solutions to identified challenges, in line with the DRM framework. In Figure 3.2 the relation between the DRM framework and the empirical studies included in the thesis can be seen.

![Figure 3.2: The included empirical studies and appended papers positioned in the DRM framework](image-url)
Furthermore, two additional empirical studies were performed within the research project, from which publications are not included in the thesis. Even though direct results from these studies are not included in this thesis, it is relevant to mention them since these studies have been conducted by the author within the frames of the research project, and therefore had an indirect influence on the research published in this thesis. Early in the project an observation study in an ongoing car project was carried out. The author gained important experience in how to conduct observation studies regarding engineering meetings in conceptual phases, concerning both the content of the meetings and methodological lessons such as entering the field and taking field notes. Prior to the Dev&Elab Study, an interview study was made in order to explore and gain insights from other industries, companies or other parts of the case company regarding how they experienced the concept decision-making process and ways to improve it. These interviews gave the author some indirect input to the development of support for concept decision making, and should therefore be mentioned.

In the research project a combination of using retrospective studies and studies of ongoing operations was chosen in order to triangulate and shed light on the process from different perspectives. The different approaches have different strengths and can complement each other, and combining the two types of case studies can help to mitigate bias (Leonard-Barton, 1990). In retrospective studies the answers regarding the outcome of the project are known (successful or not); the actors may have gained distance, which makes reflection easier. Limitations are, however, that people are prone to forget. Therefore it might be a risk to overemphasize what is documented, which does not reflect the major activities that are never documented. Following on-going projects offers the benefit of making observations and detecting activities that would not be reported in retrospective interviews and document searches (Wickelgren, 2005), providing a close-up view of patterns as they evolve over time (Leonard-Barton, 1990).

Which cases to study should be selected carefully (Eisenhardt and Graebner, 2007). In this research project one extreme (and retrospective) case was studied, and the rest were chosen due to a combination of accessibility and content of the development projects. Atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied (Flyvbjerg, 2006), being unusually revelatory, and opportunities for unusual research access (Yin, 1994). In the choice of cases to study, the author has to trust Flyvbjerg (2006, p.233) who states: “Like other good craftspeople, all that researchers can do is use their experience and intuition to assess whether they believe a given case is interesting in a paradigmatic context and whether they can provide collectively acceptable reasons for the choice of case.”

In Table 3.1 an overview of the empirical studies included in the thesis is given. The overview briefly describes the purpose, methods used, how each study relates to the different stages in the DRM framework, and to which appended paper(s) each study has contributed. In the following sub-sections the included empirical studies will be presented in more detail.
Prior to the empirical studies the initiation of the project, which can be said to correspond to the Research Clarification stage in the DRM framework. The research project was initiated in the case company and was developed in collaboration with academia before it was officially started. The initiation of the project was driven by an underlying assumption that the concept decision-making process can be improved. An improved decision-making process would contribute to development of better products, while spending less time and resources on rework. Since these wanted long-term effects will probably not occur during the time of the research project, the criteria are in this case viewed more as guiding principles for a primarily discursive evaluation of the research results.

### 3.5.1 Spectacular Case (Spectcase)

The purpose of the Spectcase study was to investigate a retrospective case in the case company. The case can be considered as extreme in the sense that the outcome of the early concept decision was not successful and rework had to be initiated in later development phases. Through hard work, the product was launched on time, and to the right specifications, and this case was selected for the research study since the company wanted to learn from it. The aim of Spectcase was to gain more understanding of what went wrong in this specific case and to identify what influenced the decisions made, in line with the purpose of DS-I (Descriptive Study I) in the DRM framework.

Semi-structured interviews and archival search were used to gather the empirical data. The interviews (nine) covered respondents from both project and functional organization, and the archival search encompassed gate reports and design reviews retrieved from the company’s documentation system. Based on the collected empirical data, a case description including a chronological picture of the course of events was

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<table>
<thead>
<tr>
<th>Study</th>
<th>Purpose of study</th>
<th>Related to DRM</th>
<th>Selection of case</th>
<th>Methods</th>
<th>Sampling of participants</th>
<th>Used in paper</th>
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<tbody>
<tr>
<td>Spectcase</td>
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<td>DS I</td>
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<td>Interviews (9), archival search</td>
<td>Purposive, roles in functional and project organization</td>
<td>B, C</td>
</tr>
<tr>
<td>Compcase</td>
<td>Comparison externally to another product-developing company</td>
<td>DS I</td>
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</tr>
<tr>
<td>Curr&amp;Fut Study</td>
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<td>DS I, start PS</td>
<td>General, purposive</td>
<td>Interviews (33)</td>
<td>First wave purposive, then chain referral</td>
<td>A, D</td>
</tr>
<tr>
<td>Dev&amp;Elab Study</td>
<td>Develop improved support and elaborate on the impact regarding applicability and usefulness</td>
<td>PS, DS-II</td>
<td>Purposive</td>
<td>Synthesis, Observations (16 weeks), archival search, interventions</td>
<td>Purposive, project and functional organization</td>
<td>E, F</td>
</tr>
</tbody>
</table>
created, as well as a list of problems identified in the case. The chronological picture and list of problems were presented to, and verified by, the respondents in a verification workshop. In the discussion in the verification session, the chronological picture was complemented with some smaller but significant events that were brought to mind when the respondents reflected upon the total case description compiled. The case description and the interviews were analyzed in order to learn what had influenced the concept decision, and in the analysis a number of dependence factors were identified. These findings were then discussed and verified in the organization.

The results from Spectcase are mainly reported in Paper C (dependence factors), but also serve as a basis in the comparison with another product-developing organization (Compcase) in Paper B regarding characteristics of the concept decision-making process.

3.5.2 Comparison Case (Compcase)

Compcase had the purpose of further investigating concept decision making, by examining another product-developing company as regards how they manage their concept decisions. This was made in order to make a comparison with the case company, and to look for similarities, differences, and identifying general issues present in any concept decision making, still addressing the purpose of DRM DS-I, i.e. widening the understanding of the current situation.

The company selected for a comparison also works with complex products including manufactured goods with embedded software, with long development cycles. The comparison company operates in the heavy transportation business. Even if both companies develop products for a global market, the business models differ regarding how their development projects are initiated and their products sold. Six semi-structured interviews were conducted in the comparison company, using an interview guide based on the one used in Spectcase in order to use the same questions, and to facilitate a cross-case analysis. Respondents were purposively selected as representatives from both project and functional organization. The transcribed interviews were the basis for the analysis. The material was first analyzed within the comparison case and then in a cross-case analysis with the Spectcase (Eisenhardt, 1989), before comparing the empirical results to studied literature. In the comparison of the two companies a number of common characteristics of the concept-decision making process were identified.

The Compcase results are reported in Paper B where the findings are compared to results from the Spectcase study.

3.5.3 Current and Future Study (Curr&Fut Study)

The Curr&Fut Study aimed to explore the understanding of concept decision making at the case company. An additional purpose of this study was to capture what the practitioners themselves would suggest regarding how to improve the concept decision making. Therefore this study can be said to be related to the DRM framework DS-I but also the start of PS (Prescriptive Study), which is intended to develop support addressing the issues identified in the current situation.

The empirical study focused on one engineering department in order to elucidate the decision-making process from different viewpoints, i.e. by interviewing individuals at different levels in the organizational hierarchy, covering both functional and project roles in the matrix organization. The approach also included respondents from other parts of
the organization to validate findings from the case engineering department. Respondents were asked to describe how the concept decisions are made, how they should be made according to the company’s guidelines, as well as what kind of possibilities were seen for improving the company’s concept decision making. The questions asked were directed to the ordinary operations; hence no specific case project was focused upon. 33 semi-structured interviews were conducted, using purposive sampling in the first wave, followed by sampling through chain-of-referral. The analysis of the data was performed in sequences and was characterized by iterating in a number of dimensions: between text analysis and display of data, as well as between deep dives and overall synthesis. In the analysis, general characteristics and challenges were identified. In the analysis also intrinsic conflicts in the process that managers and co-workers have to deal with in their daily work were identified, pointing to underlying causes of the challenges experienced by the respondents. Further, the respondents’ ideas of how to improve the concept decision making in the company have contributed as an input for developing improved support later in the research project. The findings have been presented and discussed in the case company.

Results based on the Curr&Fut Study are reported in two papers included in the thesis. Overall characteristics of the concept decision-making process are reported in paper A. Yet another analysis including inquiry regarding challenges and their underlying causes resulted in paper D, which highlights challenges and intrinsic conflicts in the concept decision making.

3.5.4 Develop and Elaborate Study (Dev&Elab Study)

The purpose of the Dev&Elab Study was to develop support addressing the challenges identified in concept decision making in the previous descriptive studies. Another purpose was to elaborate on the developed support, including initial evaluations regarding usefulness and applicability of the intended support in the case company. This was done in cycles, inspired by an action research approach involving practitioners in the development and elaboration of the support, and is related to both PS and DS-II (Descriptive Study II) in the DRM framework.

The development and elaboration of proposals for improvement of the concept decision making formed an iterative process covering literature studies, empirical studies, and interaction with practitioners looping Development → Proposals → Evaluation → Development etc., in three loops, extended over a period of 18 months (see Figure 3.3 for an overview).

![Figure 3.3: Activities within the Dev&Elab Study](image)
Initial proposals for improving the concept decision making were developed by the research team based on literature and the preceding descriptive studies in the research projects as the first loop. The second loop involved the research team, extended with two practitioners, who discussed, developed and evaluated proposals for improvement. In the third loop, the Reference Group of the project evaluated and prioritized the proposals both in a group discussion and as individuals. It was also decided that the insider researcher (the author) should make further observations in the concept phase of an ongoing project, so as to capture the everyday concept decision making in order to understand how prioritized proposals for improvements could fit into the actual process. In addition to that, practical tests of two of the developed proposals for improvement were decided to be performed in the case organization.

The observations focused on a number of forums, defined as official decision-making meetings, within both project and functional organizations, during a period of 16 weeks. The observations were complemented by interviewing and discussing with people responsible for the observed meetings, and archival search where the official meeting minutes were compared to the field notes taken during the observations. Additionally, the author was provided with a desk close to a number of key individuals in the organization, which gave the opportunity to capture contextual information. Further, the two practical tests of proposals for improvement were conducted in parallel. Test #1 involved arranging seminars, i.e. education, regarding decision making. The seminars were called ‘Concept Decision Making: Theory and Practice’ and were arranged for managers and co-workers in the organization so as to enhance the awareness and knowledge regarding decision making. In total six seminars with approximately ten people in each were arranged. Test #2 had the purpose of improving the decision making of a specific team. Therefore, the author acted as an observer during the meetings, and then gave feedback to the meeting chair and secretary between the meetings.

Based on the tests and observations, yet another development step was taken. The proposals were conceptualized into a model that included a number of “modules” for improving concept decision making. The modules were evaluated (theoretically) by the research team as well as practitioners, regarding usefulness and feasibility to implement. Further, during the process, preliminary and final results have, at an aggregate level, been presented to and discussed with members of both project team and functional organization in the company.

In Paper E, descriptive results from the observations are reported, capturing the deliberation process in a projects’ official decision-making forum regarding technical solutions. In Paper F, a model for improving a company’s concept decision making is presented and elaborated on.

### 3.6 Quality assessment of conducted research

In order to make legitimate claims and conclusions based on one’s research, a researcher has to be able to argue and justify that the conducted research is fulfilling appropriate quality requirements. Different researchers advocate different ways to assess the quality of research conducted, but the crucial issue is, according to McNiff and Whitehead (2000, p.209): “How will I ensure that any judgements I might make are reasonably fair and accurate?” Therefore this section will provide descriptions of the actions undertaken by the author
to achieve high-quality research, bearing in mind that the overall guiding principle has been to create actionable knowledge, useful for product-developing organizations.

In the design and execution of the research studies several actions have been taken to address the quality of the research, such as in selection of cases, methods, and respondents:

- **Selection of cases to study.** The research project has included a number of different cases and they have been selected in order to elucidate the research questions from different perspectives. A combination of ongoing and retrospective cases enhances both internal and external validity according to Leonard-Barton (1990). In addition, different interview studies were performed in the case company at different occasions, complemented by interviews in yet another company.

- **Selection of proper methods for data collection.** Qualitative methods were used in the data collection, guided by the research questions, searching for understanding. Different methods were used in order to triangulate (Yin, 1994): semi-structured interviews, observations and document search. For example, semi-structured interviews with open questions were chosen in order to obtain the respondents’ answers, opinions and priorities, applied in interviews with respondents carefully selected in the organization.

- **Selection of respondents.** The respondents were carefully selected, using both purposive sampling and chain-of-referral.

- **Rigor in the execution of the research.** In the data collection, data analysis, and drawing conclusions, rigor is demanded, ensuring that results and relations in the conception model are reliable (Bryman, 2008). Therefore the author has aimed to apply the selected methods in a strict and systematic way, while gathering enough data. For instance, all interviews were recorded and transcribed. An insider/outsider collaboration has been utilized in the analysis of the empirical data. This triangulation has been used in order to mitigate any insider biases, or preconceived ideas, i.e. aiming to create a distance from the studied organization and being more objective.

In qualitative research, reliability means not only being thorough, careful and honest in carrying out the research, but also about being able to show others what has been done, i.e. providing proper descriptions and documentations of the research process (Yin; 1994, Robson, 2002). To provide clear and detailed description of how and why data were collected is a key activity in order to make it possible for others to judge the conducted research (Feldman, 2007; George and Bennett, 2005). The author has tried to give an account of the methodology, even if replicability is not relevant in this type of research (Patel and Davidson, 2003).

Validity is concerned with the integrity of the conclusions generated from the research, whether the intended research purpose has been fulfilled, and whether the findings are ‘really’ about what they appear to be about (Kvale, 1983; Patel and Davidson, 2003). Feldman (2007) raises the question whether validity should be used in qualitative research since qualitative studies do not measure anything *per se*. The purpose of qualitative research is rather to describe, interpret and understand (Feldman, 2007). However, Brydon-Miller et al. (2003) assert that action research meets criteria of validity testing more effectively than do most other forms of social research. When other researchers worry about objectivity, distance, and controls, action researchers worry about relevance and social change, and validity is tested in action by the most at-risk stakeholders (Brydon-Miller et al., 2003). Further, Reason and Bradbury (2008) argue that good
knowing rests on collaborative relationships, and an understanding of value and purpose, as well as more traditional forms of intellectual and empirical rigor, regarding validity and quality in research.

Since the study is well grounded in practice (initiated in industry, and based on empirical studies in industry), as well as in literature, the relevance of the conducted research, as defined by Bryman (2008), is ensured. During the whole project, there has been a closeness to the researched organization, and a continuous dialogue with the Reference Group of the project regarding both results and the project itself. Through conducting the research studies in real industrial settings, an industrial validation has been provided (Barth et al., 2011). In addition, preliminary and final results have been presented and discussed with the organization, which is in line with Verification by Acceptance as defined by Buur (1990). Verification by Acceptance means that statements of the theory, as well as models and method derived from the theory, are acceptable to experienced designers (Buur, 1990).

External validity concerns whether results can be generalized and transferred to other contexts, beyond the one that has been investigated (Bryman 2008; Robson, 2002; Yin, 1994). Conducting in-depth studies in one case organization provides a weak possibility for transferability, since it is very context-dependent (Voss et al., 2002). However, to make general conclusions has not been the primary target, in line with what Westlander (1999) stated regarding action research: instead the aim is to create value for the specific context that is researched. Flyvbjerg (2006) emphasizes the value of practical knowledge and that a descriptive, case study without any attempt to generalize can definitely be of value. Such a study can lead to understanding of a phenomenon and what variations this phenomenon shows in relation to its context, and therefore generalizations may be made for similar situations and contexts (Patel and Davidson, 2003). Flyvbjerg (2006) further argues that generalization can be made if the case is chosen very carefully, and that a case study may be central to scientific development via generalization as a supplement, or alternative to other methods. Therefore, the documentation of the research process is of crucial importance.

It may be interesting to clarify the researcher’s point of departure, giving the reader a possibility to judge the degree of objectivity and whether the researcher allowed personal values to intrude (Bryman, 2008). In order to elucidate values that can interfere, the thesis has explicitly stated that the author is a member of the studied organization. Finally, by describing the author’s previous experience from the studied organization, and inherent closeness to and pre-understanding of what is studied, the author hopes that this will contribute to assuring the reader of the trustworthiness of the research findings.
4. Summary of Appended Papers

The research objective in this thesis has been to explore and understand, and to synthesize how to improve, decision making regarding technical solutions in early product development phases, i.e. concept decision making. This chapter provides summaries of the six appended papers and their contribution to the thesis. For more in-depth details, readers are directed to the appended papers.

4.1 Paper A


Paper A aimed to explore the concept decision-making process in order to identify its characteristics. Moreover, the study captured potential improvements of the concept decision making, identified by the practitioners themselves. The results are based on in-depth interviews (33) with experienced concept development and management practitioners in the case company.

The study shows that the word 'concept' was used with somewhat different meanings, mostly depending on what part of the organization the respondent represented. Interestingly, about a third of the respondents also associated the word 'concept' with the concept phase, and with the mindset used when investigating solutions on a higher abstraction level, e.g. being prepared that everything can change later. Thus, besides the general definition of 'concept', the study implies that 'concept' also can be a state of mind.

None of the respondents could give an account of the total decision-making process, and the respondents reported their own pictures which were fragments of the total process. The paper reveals that concept decisions grow from a process, creating a complex and complicated web of interconnected minor and major activities. Therefore, a major result of the empirical study was that a concept decision is not made at a specific point in time; instead a web of interconnected actions forms the multiple decisions that finally define the content of the input to the next phase of the project, the detailed design stage. It was also found that most of the time is spent on refining solutions used in previous projects, instead of developing completely new solutions. Degrees of freedom were often connected with whether the system was a platform solution or a unique solution. When evaluating solutions, many of the evaluation criteria were not explicitly expressed, nor were the criteria prioritized. Instead, the criteria used were often the ones that the developers themselves identified as important for the product. Further challenges in evaluating solutions and comparing alternatives were detected when the solutions had different maturity levels, since it was found difficult to objectively compare e.g. a proven certified solution with a technology in the research stage.
The internal instructions state that a choice of solution should be made, but do not specify how this should be done. Several respondents admitted that they had not read any instructions on the matter. However, they said that they knew how to proceed anyway, based on their own previous experience or on discussions with their colleagues and managers in their daily work. The template for the system selection was well known and respondents from all the hierarchical levels referred to this template (where a number of alternatives and a number of criteria should be listed). Therefore the template can be considered as an important passage point in the decision-making process, having displaced power, and should be regarded as a potential tool for implementing changes of the concept decision process. The awareness of the displaced power of the templates is something that ought to be highlighted in the case company. Further, the template includes a weighting function for the evaluation criteria; some of the respondents did use it, and some of them ignored it. However, they all thought that the discussions, regarding ranking and weighting of criteria, were the most valuable element in the process, and they expressed that if the exact figures were focused upon too much, qualitative judgment based on competence and experience would be lost.

It was experienced in the development projects that too often the chosen system solutions were discovered not to work together sufficiently on the complete product level, i.e. the systems were not compatible. Here the respondents highlighted a major challenge in concept development, namely to know that the systems in the complete product can interact properly, without having the opportunity to do any detailed analysis. To address this, coordination and clear interface definitions are required, but also an attitude of each system-responsible person to avoid sub-optimizing one’s own solutions. A way to hinder this could be to sit together in the office for a limited time. Another way to guide the development teams could be that an approach for criteria weighting is decided by the project management, and communicated to the engineering departments. This information could provide a clear vision of the product and the expected customer profile to be used when evaluating solutions.

The study highlighted a need for basic engineering work on each system, in order to build a profound experience. Such solid experience, also including knowledge of the competitors, is required in order to make early evaluations of solutions, and was something frequently mentioned. Related to this, there were wishes to have more concept engineers. These concept engineers should have extensive competence, covering deep and broad technical knowledge, great experience, but also knowledge of surrounding systems in order to develop, design and evaluate their own solutions on an abstract level.

Management in its many aspects was identified as an important factor for successful concept decisions. First, a distinction between the different needs regarding managerial processes and methods in concept development and the later phases of product development was emphasized, highlighting risks of using methods from later development stages in concept development in an ambition to reach higher efficiency. Second, the managerial approach in early development stages should be to foster the right climate, for example through rewarding successes, as well as setbacks, but to punish inactivity. Third, to use managerial tools, such as asking co-workers the right questions, and pay attention in order to bring meaning to the work done. Fourth, management was pointed out to be the carrier of the vision, and of the brand identity. Having the vision and brand identity properly communicated helps the co-workers to align their work and
prioritizations when making concept decisions. Therefore the management should advocate these issues so that every minor decision affecting the concept decisions can be matched to a clear overall vision, not sub-optimizing each system solution.

Applicable for both managerial roles and concept engineers is that they should be able to work under uncertain conditions, which therefore puts demands on how those positions are staffed. It is also important, in these stages, to have an open climate which signals that it is accepted to make mistakes. This is a question of attitude, where the management has to provide role models. Specific challenges in concept decision making, such as immature basic data or different maturity levels of alternative solutions, may be addressed by increasing the knowledge in the organization of psychological traps and biases in decision making.

This paper contributes to the thesis by identifying the concept decision-making process as a web of interconnected actors at several levels. Moreover, the paper clarifies that enhancing the basic engineering knowledge, and creating the right mindset for concept decision making, but also improving ruling documents such as the template for system selection, are means for increasing the possibility of improved concept decision making.

Distribution of work between authors: Kihlander and Ritzén planned the study together, and Kihlander conducted the interviews. Kihlander performed the analysis and writing supervised by Ritzén.

4.2 Paper B


The purpose of Paper B was to make comparisons between the case company’s concept decision-making process and the corresponding process in another product-developing company. The aim was to increase the understanding of how concept decisions are managed in product development in practice, and this paper presents identified deficiencies in both theoretical models and industrial product development.

Both of the investigated companies develop highly complex products for the global market, but the business environments for the two companies differ regarding how their development projects are initiated and their products sold. The car projects (in the case company) are initiated according to an internally defined cycle plan and then the products are sold to customers on an open market. The comparison company operates in the heavy transportation business. These products are sold to other businesses or organizations (e.g. cities, regions or governments) and the projects are initiated through a bidding-quotation process between the company and its customers. Interviews were made in the two companies, and a cross-case analysis was made as the basis for this paper.

A number of characteristics of the concept decision-making process were identified in the two companies. The proposed stepwise ‘generate, evaluate and select’ process of concept development found in literature, i.e. generating a number of alternatives that are evaluated using a structured concept evaluation method, was not followed by the companies. The results imply that actors in the concept development, instead of developing and evaluating different alternatives (as recommended in theory), worked on
one main-track solution in the concept development, and were rather struggling with developing a (as in any) solution that would fulfill the specifications. Therefore, concept decision making, as reported in the empirical study, can be said to involve more of accepting deviations (prioritizing, compromising and doing trade-offs) from a main track than choosing between alternatives.

Findings from the two companies showed that it was difficult to separate concept decision making from concept development activities, since the respondents did not report any explicit decisions or explicit decision makers. Therefore, this paper concludes that concept decisions are embedded in the development of the concepts. In both companies, respondents were unable to report the exact course of events in the concept decision-making process. The inability to report the total decision-making process may have diverse causes. It may be impossible for a respondent to describe the total decision-making process, or perhaps a decision occurs because there is no more time to iterate further and it is therefore essentially a non-decision. Moreover, the respondents were apparently aware neither of the total decision-making process, nor of their own individual processes.

It was reported in both companies that there was no common way in which decisions were performed within the companies, and that decisions were made partly ad hoc. Neither of the companies employed any official method for concept evaluation with explicit weighting of criteria used. Earlier research has shown that not only formal factors influence the concept decisions, which these studies clearly confirmed. In both companies it was found that different individuals, such as a customer or the technical project leader, influenced the decisions.

Both companies have internally defined and documented product development process models, including the phases of concept development, detailed development and industrialization. Process maps, role descriptions, and checklists for different occasions in the projects are also available as operational support. In both companies the internal process descriptions were available on intranet or in printed versions, but were hardly ever studied by co-workers in the projects. The respondents insisted that they knew where to find the instructions if they wanted to, but that they have not prioritized a search for that kind of information.

That there is a gap between theory and practice has been stated in several studies in previous research. This paper contributes by extending that discussion, highlighting the role of internal formal working procedures, which has not been sufficiently discussed in previous engineering design research. Therefore, the authors would like to add the entity of companies’ ‘formal procedures’ when discussing the gap between ‘theory’ and ‘practice’ (Figure 4.1). These different gaps may exist for several reasons. Methods may not fulfill the needs of product development practices, and might therefore be disregarded. Furthermore, organizations may nurture habits that hamper utilization, such as a stressful climate where support methods may be seen as a hindrance in practice; i.e. there is a major difference between having methods available in the company, and being able to use those methods.
The findings indicate that the transition from theory to company-specific procedures includes a risk that theoretical models are not used to their full extent. Theoretical models in literature seem to show an idealistic picture of product development, which may be required to be able to capture the overview of the models at all. Therefore, it is questionable to what extent those idealistic models support the product development in practice. Also, it is stated in the textbooks that reality is more complex than what the models show; unfortunately, this information seems to be peeled off when designing a company’s internal procedures. This has the result that the company’s formal procedures do not reflect all comments related to the models. For instance, iterations are not included in the company models, and are seldom planned for in industrial projects. Ideally, companies should be challenged to be more aware of the role and implications of their internal formal procedures. It is concluded that both literature and practice could improve in order to support the actors in the concept decision-making process, and changes are required in theory as well as in the companies’ internal working procedures.

In order to improve theory and practice regarding evaluation of alternative solutions (unlike working with one solution), the authors suggest that a change of mindset is needed. Today’s search for convergence leads decisions to be made gradually, and this striving for convergence might restrict the solution space too early. The mindset needed is to have an acceptance of working with a not too detailed solution space, allowing for parallel alternatives, and an acceptance of exposing conceptual solutions for evaluation. The mindset has to be present in both the development team and in the management.

Paper B’s contribution to the thesis is that the concept decision making was found to be embedded within the concept development, which strengthens the perception of the concept decision making as a complex process. Also, the paper contributes by pointing out the role of a company’s internal instructions, as well as by widening the discussion regarding a gap between theory and practice.

_Distribution of work between authors: Kihlander performed the planning, conducted the interviews and made the analysis. Ritzén was involved in the analysis and writing._
4.3 Paper C


Paper C reports from a retrospective case study, where the product was launched on time and to the right specifications. However, in the project the co-workers experienced a lot of frustration, mainly related to the working procedures and in particular to a specific concept decision. One engineering department had to spend extra time and resources in the later development phases in order to solve problems resulting from a less successful concept decision made in earlier development stages. This case was selected for the research study by the company since they wanted to learn from the case in order to avoid similar situations in the future.

The purpose of this paper was to find out what happened and how predictable and unpredictable events influence the concept decision-making process in the studied case. The study encompassed both interviews, with nine purposive selected respondents from project and functional organizations, and archival search. In the archival search, gate reports and design reviews were retrieved from the company’s official documentation data base. Based on the empirical data, a chronological picture of the course of events and a list of problems (including both causes and symptoms) were created. This case description was discussed with and verified by the respondents.

It was found that making concept decisions is a complex process which is influenced by both formal and informal elements. In the analysis of the empirical data, five high-level dependence factors were identified as influencing the concept decision made: Project and Product Request; Supporting Structures and Routines; Individual Competence and Driving Forces; Teamwork and Company Culture; and Contextual Circumstances. In Table 4.1 the dependence factors can be found, including sub-factors identified.

<table>
<thead>
<tr>
<th>Main factor</th>
<th>Sub-factors</th>
<th>Form</th>
<th>Level</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project and Product Request</td>
<td>• Project request</td>
<td>Formal</td>
<td>Project</td>
<td>Project-specific</td>
</tr>
<tr>
<td></td>
<td>• Project goals</td>
<td></td>
<td></td>
<td>New set-up for each project</td>
</tr>
<tr>
<td></td>
<td>• Product requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Project connections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporting Structures and Routines</td>
<td>• Area of responsibility</td>
<td>Formal</td>
<td>Organization / company</td>
<td>Valid for all projects in the organization</td>
</tr>
<tr>
<td></td>
<td>• Procedure for reporting</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Procedure for decisions</td>
<td></td>
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<tr>
<td></td>
<td>• Form of basic data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual Competence and Driving Forces</td>
<td>• Individual goals and driving forces</td>
<td>Informal</td>
<td>Individual</td>
<td>Not project-specific</td>
</tr>
<tr>
<td></td>
<td>• Goal comprehension</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Skills for listening to and screening information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Experiences, Tactics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Technical knowledge</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Company Culture and Team Work</td>
<td>• Working climate</td>
<td>Informal</td>
<td>Team</td>
<td>Between individuals</td>
</tr>
<tr>
<td></td>
<td>• Team spirit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contextual Circumstances</td>
<td>• Unplanned circumstances</td>
<td>Informal</td>
<td>Environment</td>
<td>The environment, the surrounding world</td>
</tr>
<tr>
<td></td>
<td>• Robust organization</td>
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<td></td>
<td>• World economy</td>
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<tr>
<td></td>
<td>• Mergers and acquisitions</td>
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<td></td>
<td>• Market changes</td>
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</tbody>
</table>
It was concluded that tools and parameters used for steering the decision-making process in early product development phases do not cover all aspects that influence the actual decision-making process in industrial settings. To successfully manage the concept decision-making process, all identified dependence factors should be considered. For instance, the concept decision process is a human-related process and therefore cannot be solved solely by structured methods and tools. Thus, supporting structures and routines need to be improved in such a way that the formalized processes also can allow and handle more informal factors. Proposals for this improvement should therefore have different characteristics and correspond to the different levels of perspective (Individual, Team, Project, Organization and Context).

This paper suggests that just knowledge regarding the dependence factors influencing the process will improve it, i.e. having a meta-knowledge. By making managers aware of the dependence factors, they are given a greater possibility to improve their way of managing decision making during the concept phase. Managers and co-workers need training in discovering the causes and effects in decision processes, and a continuous reflection upon the working method is suggested. As a consequence they will be more prepared to handle the challenges that will occur during the concept decision process, and be able to make decisions in a more conscious way. Hence, companies should find out how to address their own context, and define various actions for improving the concept decision-making process addressing all the identified different levels.

The paper contributes with description of dependence factors. This has implications for research such as development of methods and working procedures able to take the more informal factors into consideration even in situations corresponding to hard-pressed industrial situations. Further, the study identified the need for making the managers and co-workers aware of the decision-making process and what might influence it.

Distribution of work between authors: Kihlander, Janhager and Ritzén had a close collaboration in all parts of the study. Kihlander had the main responsibility for the data collection, where Janhager supported Kihlander during the first interviews.

4.4 Paper D

Kihlander, I. and Ritzén, S. (2011) Compatibility before completeness – identifying intrinsic conflicts in concept decision making for technical systems (Submitted for journal publication, 3rd round of review).

In Paper D the underlying causes of the difficulties in making the right concept decisions are investigated. In this in-depth study in the case company, one engineering department was focused upon in order to elucidate the decision-making process from different viewpoints. The purpose of Paper D was to contribute to a deeper understanding, and to create new knowledge crucial for developing applicable ways of working in practice, as well as to develop theory on management of product development processes.

A grand total of 33 interviews were conducted, where the respondents explained the current concept decision process, and how it is supposed to be according to the company’s internal instructions. Yet another theme in the interviews was how the practitioners thought the concept decision process should, and could, be improved. Paper D is related to Paper A since they are based on the same set of interviews, although pursuing different analyses guided by different research questions. The analysis of the data was performed in four main sequences and was characterized by iterating in a
number of dimensions: between text analysis and display of data, between deep dives and overall synthesis, and between actor and process perspectives.

The study illuminated characteristics of the process with formal procedures as well as informal conscious or unconscious actions that together result in a final concept. The study clearly reveals that the process is far from rationalistically managed as it appears in many product development models. Not surprisingly, concept decision making was found to be governed not only by technical product requirements, but also by factors related to people, and to interactions between people. The study also disclosed that, in complex product development, where a product is a combination of several systems working together, the major challenge in concept decision making is that system solutions first need to be compatible with each other before they are completely developed, i.e. to have compatibility before completeness. This means that actors in the development process need to know that conceptual solutions are good enough to advance into detailed development without being able to conduct complete detailed analysis of proposed system solution alternatives.

Further analysis of the material showed that there were intrinsic conflicts in the decision-making process, due to the organizational and product complexity, and related to the fuzziness of early phases, pointing to underlying causes of the difficulties in managing the concept decision making. Intrinsic means that the conflicts are omnipresent in the concept development process and have to be handled in the daily work by managers and co-workers. Four intrinsic conflicts were identified:

- Different ways of understanding the overall development process as iterative (engineers) or stepwise (managers) may obstruct the decision making and concept development work by hindering communication, and result in different views of the work’s progress and thereby a risk of wasting valuable resources.
- The constant imbalance between scarce resources and development efforts leads to questions regarding optimizing solutions versus reaching a satisfactory solution. Therefore, decision makers face the challenge of effectively utilizing the available development resources and developing solutions that are good enough.
- The ambiguity of criteria for evaluating solutions, using explicitly defined or implicitly interpreted criteria, means that there are aspects influencing the decisions which are not consciously taken care of. This may hinder the work of aligning the system solutions.
- To compose a complete car from the technical systems developed in parallel and within departments delivering to several projects may result in colliding goals between projects and departments. Therefore it is an inherent consequence of the organizational complexity to have to prioritize between the complete product and the long-term system strategies.

In order to achieve compatibility before completeness, high standards are required of both actors and operational support, such as supporting instructions and checklists. People, or rather individuals, were found to be crucial elements in the decision making, calling for comprehensive and solid engineering skills in the concept development. Management skills, specifically for early development phases, were also asked for, e.g. to encourage and stimulate the climate needed for innovation: actors should feel safe to act, although facing a risk of failing or making mistakes.
The authors suggest a number of means to address these intrinsic conflicts, such as enhancing actors’ awareness of psychological biases. It is also suggested to have clear and well-communicated visions regarding both product and development process, in order to guide individuals’ daily judgments and trade-offs that have to be made. Further, this paper argues that enhancing actors’ awareness of these intrinsic conflicts and subsequent consequences will improve the quality of the concept decision-making process and increase the likelihood of making good concept decisions. Hence, there is a need for individuals to handle their biases or at least be aware that biases can be present.

Challenges for those who aim to develop support for actors, facing the specifics of decision making in the concept stage, are discussed in the paper. Any suggested support models or methods have to give involved actors sufficient support but still be flexible enough to be applicable in actors’ different contexts. The suggested operational support should therefore address not only the actual decision process, but also how working procedures are diffused in the organization.

The contributions of Paper D to the thesis can be summarized as identifying a major challenge in concept development, namely to achieve compatibility between the systems in a product without being able to make any detailed analyses. Further, a number of conflicts intrinsic in the daily operations that have to be handled were identified and discussed.

Distribution of work between authors: Design of the study and gathering of empirical data were carried out by Kihlander. Analysis and writing were done by both Kihlander and Ritzén with Kihlander as main contributor.

4.5 Paper E


The research objective of Paper E was to make an in-depth study regarding actions of deliberations made during meetings officially defined as decision-making meetings, regarding the technical content of the product to be developed.

As identified in earlier research in product development, much time and effort are spent on tentative and implicit decisions, as well as on deliberations. Therefore, this study aimed to explore different actions in a decision-making forum with face-to-face interaction, and where participants from different parts of the organization interact in a cross-functional manner. Observation studies were conducted, following the concept phase of a development project in the case company. Field notes were taken, and formed together with the official meeting minutes and an interview the basis for the analysis. To form a complete and accurate basis for future improvements of the current decision-making process, the elements of deliberation and the involved constraints were captured as well.

The observed weekly meetings used an agenda-based design, meaning that each meeting consisted of several agenda items. The items covered a broad range of technologies and different engineering areas, and were often brought to the meeting to perform balancing between different technical areas or targets. Each item was assigned approximately 15
SUMMARY OF APPENDED PAPERS

minutes, and for each item a new set of people attended the meeting, except for the project management who were there the entire time. Therefore, this kind of agenda-based meetings is in fact a series of short, separate but connected meetings. Consequently, this makes the content difficult to overview for the participants, except for individuals participating the entire day. The study reveals a number of aspects of the meetings found to have implications for the decision-making process. Each item was only allotted a short time slot, leaving no time for deeper discussions, so the process relied on the participants’ instantaneous interactions during these assigned time slots. Hence the knowledge used in the meetings is the knowledge that the participants posses ‘by heart’, which, in turn, puts high demands on the competence of the meeting participants. Even though project management meetings have been subject to extensive research studies, the author believes that consequences of using agenda-based meetings have not been discussed to the extent corresponding to the actual usage of this type of meetings.

Further, a number of challenges in managing the decision-making and deliberation process were identified, especially for agenda-based meetings such as the investigated ones. For example, project management instantly had to judge how to demarcate the discussed problem in order to take the next step (since real problems never have clear limits). Project management also had to judge whether to continue a fruitful probing of an issue in order to finally solve the problem, or stop the discussion and move to the next item on the agenda so as not to postpone the rest of the meeting.

As stated in previous research, decision making consists of several non-linear elements. In this study it was illustrated how ‘working assumptions’ were used in the meetings as a means to reduce uncertainty and to move the decision-making process forward. These inherently preliminary working assumptions are valid until it is found that new working assumptions need to be identified. Other elements of deliberation, driving the decision process forward, were questions, which were frequently observed in the meetings. Three different genres of questions were identified, and were found to be posed by people in different roles, with different purposes:

* Elucidating questions: reinforcing the presented material, and widening other participants’ knowledge of the problem (posed by anyone, often a colleague or an ally).
* Self-enlightening questions: to enhance his or her own understanding of the problem (by managerial people).
* Argumentative questions: to falsify or diminish what is presented (by peers, often opponents).

The main contribution of Paper E to the thesis is the further exploration of the deliberation process, recognizing that defining working assumptions and asking questions (three genres identified) are used in order to reduce uncertainty and equivocality. This paper also contributes by identifying a number of implications for the concept decision-making process of using agenda-based meeting. Moreover it is highlighted that organizations ought to reflect on the consequences of employing such a design of important decision forums in early development phases. For instance, great technical competence is needed by those present in such decision-making meetings, as well as an ability of the project management to handle the identified challenges in managing the process of agenda-based meetings. To improve the decision making, starting from the current process, any improvement proposal should include consideration regarding its fit into the very fragmented process of using agenda-based decision meetings.

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Distribution of work between authors: Kihlander, as the single author, performed the empirical study, analysis and writing.

4.6 Paper F


Paper F proposes a model showing how companies can work with improving their concept decision making, given that the concept decision-making process is a weave of interconnected activities, including many actors on several levels. The model addresses challenges in concept decision making that were identified in previous work. The model was developed in collaboration with practitioners in the case company in an iterative process covering literature studies, empirical studies, synthesis and interaction with practitioners inspired by action research. Further, it contributes to theory building through creating actionable knowledge regarding how support methods for decision making in early innovation and product development could be designed.

The proposed model includes a set of activities, i.e. a number of modules that are designed with a practice-centered view, to be applicable in the present process within a product-developing organization in order to make an improvement. The model includes the modules: Seminars, Coach Teams, Coach People, Visualize the Process, Visualize Content of the Process, Checklist Start of Concept Work, Battery of Questions, and Align Every Day Decisions. The modules can be deployed each by themselves, but are preferably combined in a way that suits the specific organization.

The Seminars have the purpose of enhancing the knowledge and awareness of the decision-making process and what is influencing it. Coach Teams, and Coach People, mean coaching groups or individuals through following them in the actual process, and having coaching discussions on a regular basis. Visualize the Process aims to create a better understanding of the ongoing process. Visualize Content of the Process enhances the way to communicate the content of the process, something that is needed in the short time slots available in the agenda-based decision-making meetings. The Checklist Start of Concept Work should help the organization to review the necessary prerequisites for starting concept work, including aspects that traditionally have not been explicitly discussed before. The Battery of Questions helps actors in the process to ask questions otherwise neglected, enhancing the overall process quality. Finally, Align Every Day Decisions addresses that the management should provide a clear vision so that the co-workers can align their major and minor decisions with the overall vision, and thereby contribute to the overall results of the organization.

The holistic model is designed to include modules that address individuals as well as modules that address the team level. Some modules are meant to be used integrated into the daily work, and some for education and training, external to the actual process. Further, some modules are meant to be used in iterating between the actual process and external to the process. Finally, it should be noted that these modules cover tangible support, such as checklists and templates, as well as more intangible elements such as education and reflections. The paper elaborates on both the usefulness (i.e. addressing identified problems) and the feasibility (i.e. addressing suitability for implementation) of the different modules in the model. Initial experiences from testing the change initiatives
in the specific case context in the research project, reflecting on opportunities and limitations, are also reported.

Further, a contradiction appears when using agenda-based meetings in early development phases, since characteristics of concept development (fuzziness and uncertainty) are in glaring contrast to the characteristics of agenda-based meetings (divided into fragments and short time slots). Therefore a great challenge to address is to find ways to mediate complexity and contextual information on concept solutions in an effective way, e.g. through visualization.

It was found that an unreflective decision-making process is less successful for the organization, exemplified by items consuming valuable time while re-curring in meetings without any value added between the occurrences. A key element appearing in the study was the need for the actors in the process to really reflect on their own decision-making process, and also acknowledge the fuzziness and learn how to handle it, since it is a basic characteristic of this early development phase where changes most definitely are going to occur later. Therefore, more reflective decisions in early phases of product development would enhance decisions made directly, but most of all they would build a long-term capability over time to make good decisions in the innovation process.

This paper contributes to the thesis by proposing a model for improving companies’ concept decision making, including the suggested modules: Seminars, Coach Teams, Coach People, Visualize the Process, Visualize Content of the Process, Checklist Start of Concept Work, Battery of Questions, and Align Every Day Decisions.

Distribution of work between authors: Kihlander led the intervention study, where Ritzén participated. Kihlander developed the model and wrote the paper under the supervision of Ritzén.
5 Discussion

The previous chapter summarized the contribution from each appended paper to the thesis. The objectives of this chapter are to discuss the results from papers included in the thesis, and to clarify the contributions of the thesis. The discussion addresses the two research questions: to identify and explain the difficulties in concept decision making; and how these difficulties can be managed. Further, to enhance the understanding of concept decision making in practice, a discussion will first be provided on a number of interesting descriptive findings from the studies.

5.1 Understanding concept decision making in practice

Concept decisions are found to be made in a process, a complex weave of activities ending up in a decided concept solution, where many actors are involved. Before discussing the process and what is influencing it, some reflections are made regarding the use of the word concept, which is a key word in this research.

5.1.1 What is a concept?

The respondents defined a ‘concept’ as an idea or a rough solution, which complies with the definitions in the engineering community (e.g. Ulrich and Eppinger, 2008). In further analysis it was found that respondents’ definitions referred to different levels of the product as the complete product or the system level, depending on what part of the organization the respondents represented. People working in an engineering department referred to the system level, while respondents working with the complete product level only referred to the product level. A use of different definitions of the word ‘concept’ within the same organization has also been observed in previous studies (Setterberg, 2008). The author did not, however, register any misunderstandings or detrimental consequences due to this discrepancy. This is probably because practitioners use explicit technical terms when communicating about concepts. Therefore, this thesis will not explore this inconsistency further, and will use ‘concept decisions’ as decisions regarding technical solutions in early development phases, even though it might be perceived as ambiguous. Irrespective of system or complete vehicle level, challenges in concept decision making are present on all levels. Therefore this research, even though the empirical studies focused on a system level, should be interesting and beneficial for managers and co-workers working at all levels in early stages of product development.

The interview answers predominantly reflected the technical side of a concept, the idea in a concept according to Andreasen and Hansen’s (2002) definition, not treating the idea with a concept. This is certainly a result from the respondent sampling, where the interviews were conducted in the R&D organization. A focus on the R&D effort in innovation is quite common among scholars (Crossan and Apaydin, 2010). If the interviews also had covered respondents from the business and commercial side, definitions of ‘concept’ would probably had been more in accordance with PDMA’s (2005) definition where a concept is a combination of customer benefits and technologies needed to embody them.
Most interestingly, several respondents also referred to ‘concept’ as the activities that are conducted in the concept phase, meaning that it is a special atmosphere (Paper A). “To decide before you know” is a quote from a respondent explaining how he experienced the concept phase. Therefore, it can be concluded that to be able to work in these phases a specific mindset is needed, being prepared for that “everything can change”. This corresponds to Jönsson’s (2004) tent metaphor of decision making in early product development, where the tent pegs have to be adjusted along the way in order to get the final result. Referring to concept as a state of mind was done by people who themselves perform hands-on development, and for whom it is not only about what they should deliver (i.e. a concept solution) but also how they experience these activities and the different facets of uncertainty.

5.1.2 A complex web of interconnected activities

In the empirical studies it was concluded that a concept decision is not a discrete event happening at one single point in time. Instead a decision grows out of a process embedded in the concept development, where specific decision activities are hard to distinguish from other activities in the concept development. The empirical data showed that it takes a significant amount of elements to fall into place in order to have successful concept decisions. The emerging picture of a complex decision process was not very surprising given the conducted literature review of decision making in product development (e.g. Christiaans, 2010; Stempfle and Badke-Schaub, 2002). However, it is even more significant for the concept decision process due to the omnipresent fuzziness, since early design phases of innovation are complex and include technical, economic, organizational and social aspects (Legardeur et al., 2010).

How the actual concept decisions happened was difficult to capture in the interviews, since the respondents had difficulties in describing it, which other researchers have also experienced (Bragd, 2002; Gustavsson and Sterner, 2008; Wickelgren, 2005). Most likely this is a consequence of the respondents, as individuals, experiencing only parts of the overall process, so that it is almost impossible for any individual to know the whole decision-making process. Or, perhaps a decision occurs when the team does not have time to iterate anymore, and therefore it is more of a non-decision. Moreover, the respondents are apparently aware neither of the total decision-making process, nor their own individual processes. This indicates that the respondents do not have a language, or practice, to reflect upon decision making, which is interesting since both theory and the respondents point out that decision making is an important activity.

The process included several types of elements, corresponding to the garbage can model of decision making where solutions, problems and actors are randomly mixed (Cohen et al., 1972). However, due to the planned control points in the overall development process, such as project reviews or test series (Paper E), a kind of muddling-through occurred. This resembled the cycle pattern defined by Badke-Schaub and Gehrlicher (2003), as “reiterations of partial sequences of process steps and a controlled muddling-through”.

Interestingly, a specific pattern with actors on different levels was observed: a System Expert suggested a solution, a Department Director supported the suggestion, and a Project Manager confirmed the system selection decision (Paper A). This resembles to a certain extent the model of decision making on discontinuous innovation in the Fuzzy Front End as presented by Reid and de Brentani (2004), where the process passes
through three interfaces: boundary, gate-keeping, and project interfaces. Developing cars may not be considered as discontinuous innovation, since cars have been on the market for about a hundred years and are rarely, if ever, designed from scratch (Eckert et al., 2011). However, in investigating the decision-making process in the case company, Reid and de Brentani’s (2004) process elucidates important interfaces in the concept decision-making process, and decision makers on both individual and organizational levels.

The findings specify that there are decision makers both inside and outside the projects (Hansen and Andreasen, 2004), corresponding to organizational decision making with all inherent challenges (Kopecka et al., 2011; March, 1997). Internal decision makers may be managers or leading experts, and external entities may be fiscal authorities or customers directing what requirements the product should comply with. In the following section factors found to influence the process as a whole are discussed.

5.1.3 Dependence factors – affecting different levels of the process

The empirical studies clearly showed that more factors influence the decisions made, than what are deliberately taken care of in prescribed support methods for concept decision making, in both literature and the case company. The findings reported in Paper C demonstrate that several factors, formal (e.g. technical requirements), as well as informal (i.e. factors that are traditionally not consciously considered in concept decisions, such as working climate), influenced the concept decisions made. These were clustered into five high-level dependence factors: Project and Product Request, Supporting Structures and Routines, Individual Competence and Driving Forces, Teamwork and Company Culture, and Contextual Circumstances. The dependence factors are found to operate on different levels: Individual (goals, competence etc.), Team (interaction between individuals, e.g. teamwork), Project (performance of specific project, e.g. technical or timing targets), Organization (formal structures and processes in a company, e.g. organizational structure or checklists), and Context (events in the surrounding world). The levels are all connected in a hierarchical relationship. Individuals and team make the decision (individuals are members of a team). The team performs its tasks within a project, which is performed within an organization, and finally the organization operates throughout the environment (Figure 5.1).

![Figure 5.1: Different levels of perspective on the dependence factors](image)

Scrutinizing the identified dependence factors on the more detailed level (see Table 4.1) one might suggest that some of them are quite obvious as influencing the concept decision-making process. For instance, technical competences influencing the decisions on the ‘individual level’, the working climate on the ‘team level’, and the technical
requirements on the ‘project level’, not surprisingly. However, structural support, such as division of work or templates to be used, was also found to influence the decisions (on the ‘organization level’). Finally, through the ‘context level’ the surrounding world influences the decisions. By identifying the overall dependence factors and providing a visualization of the levels on which they influence, this thesis contributes to an enhanced understanding of what is influencing the concept decision-making process in practice. For instance, the surrounding world is somewhat hard to control, but it still needs to be considered and reflected upon. This can help decision makers to approach the complex process in a more conscious way, without becoming victims of the circumstances.

Today’s evaluation methods cover evaluation criteria mainly on the ‘project level’. This study, however, points out a need to include more evaluation criteria when making concept decisions, and that all identified dependence factors should be considered. This has implications for research since it is valuable input to development of future support for the concept decision-making process, in line with Khurana and Rosenthal’s (1998) recommendation of a holistic management of the front end process.

5.1.4 Official concept decision-making meetings

Paper E focused on investigating meetings, defined as a concept decision-making forum, since they are evident elements in the concept decision-making process. In earlier studies of management meetings it has been identified that no decisions were actually made in the meetings (Bragd, 2002; Christiansen and Varnes, 2006). However, the author observed several actions that could be labeled as decisions. Hence, it seems to be a matter of what one includes in the expression ‘a decision’. Probably, different people distinguish between decisions and the total deliberation process in different ways, representing people as both deliberation makers and decision makers (Wickelgren, 2005). This has implications for research on decision making since it becomes very important to demarcate what is studied, and to clarify what definition is used for a ‘decision’. Based on the conducted empirical studies, the author concludes that there is no single decision that constitutes the concept decision; instead it is a chain of key results as Christiaans and Almendra (2010) define it. The author recognizes both major and minor decisions along the way, and is interested in the whole process of activities that ends up in a final concept decided. Further, a difference might also be a consequence of the type of meetings observed. Bragd (2002), Christiansen and Varnes (2006), and Wickelgren (2005) observed management meetings, such as gate and project management meetings, while the meetings observed in this study had the purpose of defining the technical content of the product. Hence, what was observed in these meetings might have been the decisions that later were justified in the gate meetings (Christiansen and Varnes, 2006).

A typical decision observed in the meetings was defining a ‘working assumption’, i.e. deciding what main track to focus upon in the subsequent work. These decisions were always made with a sense of to-the-best-of-our-knowledge, and included an element of tentativeness (Hansen and Andreasen, 2004). Due to complex relationships between all the systems in the product, there were also occasions where the working assumptions resulted in implicit decisions (Lopéz-Mesa and Chakrabarti, 2007), with consequences not obvious from the start. In addition, a lot of questions were asked in the meetings by the “audience” to the presenter, and three genres were identified: elucidating, self-enlightening, and argumentative questions. The different types of questions were posed
by different actors and with different purposes: to strengthen what was presented; for individual learning; or to weaken what was presented.

The observed meetings (with the task to decide the technical content of the product) were agenda-based, meaning that for each item an external person presented the item during an assigned time slot. The specific meeting design, with an agenda consisting of many shorter items was found to have a number of implications for the concept decision-making process, which the author believes has not been discussed to the extent corresponding to the actual use of this type of meetings. Within the time frame for each agenda item, the item should be presented, understood, and concluded, which confirms the difficulties in creating forums suitable for deliberations (Jönsson, 2004; Lundqvist, 1994). During the time assigned for an item, only a part of the information relevant to the matter can be presented, suggesting an iceberg metaphor (see Figure 5.2), which points to a great challenge to mediate complexity and contextual information on concept solutions in an effective way during a shorter time slot.

![Figure 5.2: Iceberg metaphor: what can be reported during a short time-slot in a meeting?](image)

This meeting design was also found to place great demands on having the right people present – both management to make decisions, and engineering competence to instantly answer regarding any technical issues, since communication in the meetings relied on instant actions by the meeting participants, utilizing only knowledge they had ‘by heart’. For instance, the leader had to judge immediately how to demarcate a problem discussed in order to take the next step (since real problems never have clear limits). The leader also had to judge whether to continue a fruitful probing of an issue in order to finally solve the problem, or to stop the discussion and move to the next item on the agenda so as not to postpone the rest of the meeting.

Defining ‘working assumptions’ and asking questions were observed to be highly utilized means for reducing uncertainty in the deliberation and concept decision-making process. Therefore, this research contributes to enhanced understanding of the process, and defining ‘working assumptions’ can be added to the list of earlier identified elements such as tentative or implicit decisions, direction or tracks as elements driving a decision process forward. Another contribution is recognizing that the use of agenda-based meetings has implications for the decision-making process, even more significant in early product development phases due to omnipresent uncertainties. The findings point to a contradiction in using agenda-based meetings (very structured, with fragmented agenda) and characteristics of early development phases (fuzziness and uncertainty), since it is hard to fit such deliberation into tight meeting schedules (Jönsson, 2004). Exploration of this contradiction, and finding alternative ways of working, could be a strand for future research. Additionally, developed support for concept decision making should comply with the instant interactions happening in the meetings, and the need to mediate a lot of information in an effective way. For practice, it can be stated that organizations should not use this meeting design for concept decision-making in an unreflective way.
5.1.5 The role and dissemination of a company’s internal instructions

Gaps between theory and practice observed in the empirical studies confirmed results from earlier empirical studies on decision making in product development (Christiansen and Varnes, 2007; Dwarakanath and Wallace, 1995), also corresponding to the distinction between espoused theory and theory-in-action (Argyris and Schön, 1974; Brown and Duguid, 1991). However, the interviewed practitioners did not refer to the academic literature when they reflected that they did not do as “it was described”. Instead they referred to company internal instructions (Paper B). Many established product-developing companies have a body of formal documents and procedures, prescribing the companies’ work (Barczak et al., 2009), which may – or may not – be based on methods derived from research. Therefore, the discussion of a theory/practice gap should widen to also encompass a company’s “internal literature”. Hence, there are several gaps to have in mind when the aim is to improve both theory and practice. In this research project, being an Industrial PhD project, it is actually expected to contribute to all three entities: academic theory, internal formal procedures, and practice (Paper B).

Low utilization of structured evaluation methods was also somewhat expected, since it corresponds to earlier research (e.g. Salonen and Perttula, 2005), which may be for several reasons. It could be a sign that co-workers need education regarding evaluation methods or mal-practice in the company, or perhaps support methods and industry’s demand do not match (Frost, 1999). Further, there may be a discrepancy in terminology where practitioners use an adapted version of a method suggested in literature (with an official name) – aware of neither the official name nor the origin, since the primary priority is to get the work done, not how to do it (Frost, 1999; von der Weth, 1999).

Despite the scattered picture of the concept decision-making process reported, there were some exceptions that made the process converge, which is a basic idea of using support methods. For instance, the template for describing alternative systems solutions was referred to by many respondents, serving as a common reference point in the concept decision process. Hence, it can be seen as both an obligatory passage point (implying which criteria are important) and a boundary object (transferring and translating knowledge) (Carlile, 2004; Christiansen and Varnes, 2007). Identifying such a common reference point in an otherwise scattered process provides an opportunity to utilize these passage points as effective means for improvement of the process. For instance, the template can be used as a tool for change and learning, which also gives power to whoever designs the template. Wanted changes should therefore be requested in the template, e.g. asking for a system’s compatibility with surrounding systems.

In addition, the actual way working procedures are disseminated in the organization is of interest when aiming to close the gap between practice and theory. Here, Hein (1994) suggests that there should be an implementation method included in each developed support method that helps to adapt it to the circumstances. Addressing the same challenge, Geis et al. (2008) state that to successfully transfer methods from theory to practice there are requirements on the method (not too theoretical, and should be adaptable into daily routines) but also on the implementation itself (promotion of methods, and appropriate training events).

Suggested support models and methods have to give actors sufficient support but still be flexible enough to be applicable in the actors’ actual context, i.e. in the process that
unfolds as a consequence of the problem to be addressed. The need for flexibility when applying models and methods has been stressed before (Christiansen and Varnes, 2009; Tatikonda and Rosenthal, 2000), but the author believes that flexibility of support methods in practice needs further elaboration. A finding from the studied case company was that far from all respondents read formal instructions available within the company; instead they relied on discussions with their managers and co-workers. Further, a few times respondents referred to their role description when elaborating on their part in the concept decision-making process. Interestingly, this was only referred to by people who had the same task, acting as System Experts, doing the hands-on development job in early phases. A conclusion from this is that the role description could be a tool for change, but is probably not enough.

A contribution of the thesis is therefore the identification of the role of a company’s internal instructions, also pointing out challenges for companies in transforming theoretical models into formal company internal procedures. If the aim is to support management of concept decision-making process in practice, in line with Reich’s (2010) ‘correspondence’ (meaning that the ultimate test of a method is when it is used in practice), implications for research are to make theoretical models easier to adapt to different contexts, and thereby facilitate application of the suggested methods. Engineering design literature could improve how to visualize and communicate complexity in the process, and companies could become more aware of the role of their internal formal procedures. But first the difficulties in concept decision making needs to be further explored and explained, which is made in the next section.

5.2 Explaining difficulties in concept decision making

The fuzziness in early development stages contributes to several challenges, such as uncertainty and long feedback loops (Matheson and Matheson, 1998). Van de Ven (1986) and Sharma (1999) have identified a number of problems in management of innovation that apply to the operations studied, and this thesis contributes by highlighting further challenges experienced, from a bottom-up perspective.

In literature, concept development prescribes the activities: develop, evaluate, and select concept(s) in a step-wise matter (e.g. Ulrich and Eppinger, 2008). A gap between prescriptive literature, presenting step-sequence models, and empirical findings was identified in line with previous research (Stempfle and Badke-Schaub, 2002; von der Weth, 1999). A number of challenges of concept decision making, that have not been emphasized in literature to the extent that was observed in the empirical studies, will be discussed here:

- **Problem-driven process.** The development process was mainly described as problem-driven, focusing on a specific problem (Paper B). This will guide the rest of the work, i.e. starting with a problem and then letting the process unfold, instead of having a rigid general process where a problem is entered, as described in most product development models (e.g. Ulrich and Eppinger, 2008).

- **Handling interfaces.** Developing a system solution implies numerous interactions with other systems in different kinds of interfaces (e.g. geometrical or functional). Therefore, much time is spent handling these interfaces, negotiating and balancing between systems within the product, instead of developing alternative concept solutions (Paper A).
DISCUSSION

- **Re-use solutions.** Often there is an obligation to re-use solutions from previous projects, for reasons of cost and knowledge, which entails inherent limitations from the start (Eckert et al., 2001). Product development models, however, are presented as solutions developed from scratch, which is hardly the case most of the time (Paper B). Further, product developers may experience an ambiguity since, in parallel, they should re-use solutions in some areas and develop innovative solutions in other areas.

- **One main-track solution.** Alternative solutions were not always generated, even though this is recommended in the case company’s internal instructions and in literature (Nutt, 1984; Eisenhardt, 1989a). In fact, it was more usual that work was focused around one main-track solution (Paper B), similar to earlier generation-evaluation iterations identified by Dwarakanath and Wallace (1995). Respondents found it challenging, or sometimes unnecessary, to develop alternatives in parallel. For instance, in the Spectcase study the design team became too detailed too early, and alternative solutions were neither developed nor evaluated. This can be for different reasons: there are no resources to develop more than one solution; or elements of fixation or attachment are present (Cross, 2006; Jansson and Smith, 1991).

- **Difficult to compare alternatives.** When alternatives were developed, the respondents reported difficulties in comparing the alternatives, e.g. due to alternatives’ different maturity levels (Paper A). This may be influenced by individual biases, such as fixation, but can also be influenced by factors found in earlier research, such as origin or understanding of the solution, to specifically influence concept judgments (Backman et al., 2007; Reidenbach and Grimes, 1984). One way to approach this could therefore be – instead of raising the maturity of the less developed solution, since there is probably no time for that – lower the maturity of the alternative already developed, hence “peeling off” the already developed solution.

- **Not rational decision making.** Evaluations of alternative solutions were seldom made in a pre-defined way. Since neither stable preferences nor specific decision rules were used, the process did not comply with rational decision making as defined by March (1997).

A presence of psychological biases and traps might restrain individuals working in the concept development by limiting their utilization of full mental creative capacity for generating good solutions, or for evaluating alternative solutions in a fair way. This may apply to designers but also to managers and other decision makers, and when managers are fixated the impact might be larger due to their power situation in the organization.

5.2.1 **Compatibility before completeness: purpose of concept decisions on technical systems**

The crucial importance of making good concept decisions has been emphasized several times (e.g. Martinsuo and Poskela, 2011), simply because they strongly bear upon all subsequent phases of the design process, and since weak concepts cannot be turned into optimum detailed designs (Roozenburg and Eekels, 1995). The concept phase therefore aims to define what solution(s) should be developed further (Ulrich and Eppinger, 2008). But what does this mean for product developers and decision makers working hands-on in product development?

In this thesis the perspective of an engineering department, responsible for developing a great part of the car, is applied. An engineering department has expertise on its own systems but not the responsibility (or feasibility) to develop a complete product. Working on the system level adds, besides knowing that concept solutions are good enough to
advance into detailed development, the challenge of knowing that the developed system solutions work together with surrounding systems. These surrounding systems are developed by other engineering departments, and are in the same way in a phase of early development. In order to contribute to fulfilling the overall product goals, an engineering department’s task is consequently to develop its systems to a level good enough, and to ensure that its systems work later in the subsequent project – without being able to conduct any detailed analysis of the suggested concept solutions. Thus, the purpose of the concept decision making focusing on the system level is to achieve compatibility before completeness, meaning that compatibility between product systems must be met before the system solutions are completely developed. In short, it is about “to know that you know enough”. A contribution of this thesis is therefore the identification that an overarching challenge of concept decision making is to achieve compatibility before completeness. This awareness is crucial in development of complex products consisting of many systems and hence interfaces, and where management of the part-whole relationship is important to avoid sub-optimizing of system solutions (van de Ven, 1986).

For people working in these phases, a challenge is thus to hinder themselves from being too detailed too quickly (Morgan and Liker, 2006; Verganti, 1997). Even if it is easy to agree on this, the empirical studies show that it is very difficult in practice not to make premature decisions. Therefore, a competence needed for working with concept decisions is to be confident when working under uncertainty.

5.2.2 Intrinsic conflicts in the concept decision-making process

In a search for deeper understanding of challenges experienced in the concept decision-making process four intrinsic conflicts due to the product and organizational complexity were identified (Paper D). These intrinsic conflicts are omnipresent in the process and have to be handled in the daily work. The identified intrinsic conflicts that point to underlying causes of the difficulties in managing concept decision making and are described as:

Understanding of the overall development process as iterative or stepwise. The process was experienced in different ways, related to some extent to the respondent’s hierarchical level: stepwise (managerial) or iterative (co-workers). That different actors emphasize different features in development process models is in accordance with earlier research (Christiansen and Varnes, 2009; Engwall et al., 2005), where for instance a process appears more rational, the more distant the observer is (Shoemaker, 1993). Different ways of understanding the overall process may obstruct the concept work, i.e. wasting valuable resources on developing wrong solutions, not providing deliverables requested for, or aiming for conflicting targets. Therefore, implications for research are that output from research, such as prescriptive models, methods and tools, must be clear in order to create common references, and be adaptable to practitioners’ daily work.

Developing satisfying or optimized solutions. The concept decision-making process was mostly signified by iterative actions in striving to find a solution that was good enough (satisfying), similar to earlier research in industry (Styhre et al., 2010; Wickelgren, 2005), while there also were some people who pushed for optimizing the solutions. Constant imbalance between scarce resources and development efforts points to questions regarding how to effectively utilize available development resources. Since early development phases use a certain degree of judgment, and incomplete evaluations occur
DISCUSSION

(Ullman, 1997), the question of optimizing solutions already in concept development becomes interesting. It was reported in the studies that not all issues concerning a solution are revealed until the detailed development, which puts high demands on those who define parameters to be used for optimizing a solution in early development stages. If the requirements are developed in parallel with the solutions, as in the case company, there may be a risk of being trapped in analysis paralysis (Langley, 1995) – continuing to do further analysis regarding newly defined requirements, and never settling for a solution. Therefore, actors in concept decision should be aware of consequences of trying to optimize solutions already in early development stages. Further, they should be reminded that there are seldom any right (Keeney, 2004; Ullman, 2002).

Using defined or interpreted criteria when comparing solutions. Strong elements of interpretation were present in the evaluation of solution alternatives. Explicit criteria can be defined both internally in the company, or may be forcing regulations, which in turn have been found to be a lever for innovation (Lee et al., 2010). Besides the formal criteria for evaluation, it was found that product developers were guided by what they themselves identified as most important for the brand identity. If each actor in a decision process makes interpretations based on individual experience and input, there is a risk of conflicting targets. In previous research it is stated that criteria used in early phases often lack clarity compared to later stages where more explicit criteria can be defined (McCarthy et al., 2006; Schmidt et al., 2009; Yang, 2010). Therefore, evaluations in early phases have to be treated with extra delicacy, bearing in mind that criteria used in incremental and radical projects tend to differ (Schmidt et al., 2009). Thus, the actors have to keep calm and continue gather information without rushing into the detailed design where more firm information will be available (Verganti, 1997), and not apply too rigid and formal assessment (Hammudi et al., 2011; Martinsuo and Poskela, 2011). The ambiguity in using explicitly defined and implicitly interpreted criteria means that there are aspects influencing the decisions not consciously taken care of, which may hinder the work of aligning the system solutions into a complete product.

Composing a complete car from different systems solutions, prioritizing project targets or long-term system targets. To develop a complete car from many technical systems, developed in parallel and within departments delivering to several projects, may result in colliding goals between projects and departments, and can include conflicts of interest regarding attributes, systems and requirements. A person responsible for a system should deliver the same system solution to more than one project, and the person responsible for the project should integrate several system solutions from different areas. Consequently, a majority of time is spent on negotiating and balancing, thus prioritizing with a necessity to make trade-offs. A conflict concerning who should make the concept decisions was identified in the studies, which has been somewhat highlighted before by van de Ven (1986) as a part-whole relationship in management of innovation. This can result in power struggles when functional strategies of systems and project targets are not aligned, having a streak of internal politics. Either a specific project target or a long-term strategy for a product system might be sacrificed, confirming that decisions made in organizations are never neutral events (Eisenhardt and Zbaracki, 1992; Koopman and Pool, 1991). However, eventually the actors have to agree in some way, to develop the product. Therefore, having to prioritize between the complete product and the long-term system strategies is an inherent consequence of the organizational complexity.
An implication for research is that developed support must help people in handling the challenges and intrinsic conflicts discussed above. An implication for practice is to recognize these issues where an awareness may help to maneuver in the process, e.g. to use methods ensuring alternatives to be developed, which decrease impact of individual biases in evaluation of alternatives, as well as to clarify what criteria should be used. Another task for practice is to identify turn keys for change in each specific organization. Which are they – and how can they be used to improve the concept decision making?

5.3 Managing difficulties in concept decision making and improving practice

This section discusses how concept decision making can be improved in organizations. In changing practice, a focus on new models alone is insufficient (Engwall et al., 2005), and a holistic view that considers integration of technical, cognitive and social processes is recommended (Cross and Clayborn Cross, 1995; Khurana and Rosenthal, 1998).

Based on the empirical studies, it was concluded that people, for whom decision making can be considered as a skill (Keeney, 2004), are crucial elements in the concept decision-making process. These actors have to be able to handle uncertainty and complexity, e.g. by accepting flow and the fact that intuition and emotions are there as guidance (Crossan and Apaydin, 2010; Patton, 2003; Zeelenberg et al., 2008). In order to make sense of uncertainty and complexity, Matheson and Matheson (1998, p.123) suggest using the principle “Embracing the uncertainty: know what you do not know”. Not surprisingly, the importance of management was emphasized. The respondents frequently confirmed earlier research where it is stressed that management should create an innovative and entrepreneurial climate in the organization (Ekvall, 1996; Nicholson, 1998; Menzel et al., 2007), allowing fuzziness and failures (Paper A). The respondents also emphasized the importance of having people with solid engineering skills in the development of concepts. Deep and broad technical knowledge and extensive engineering experience are needed to understand the complexity in the product (Eckert et al., 2011). This requires time to learn, but also that the organization succeeds with systemic learning, i.e. learning from earlier experiences (Verganti, 1997). To have great engineering competence present in concept development and concept decision making is found not to be as highly stressed in research as it should be, based on how strongly the respondents emphasized a need for genuine engineering competence. Perhaps this is because it is taken for granted as a component in successful product development, but it should not be forgotten.

5.3.1 Key elements for improving concept decision making

Based on the empirical studies and previous research, the author has identified a number of key elements to be used in order to improve concept decision making:

Create meta-knowledge and awareness. The empirical studies all showed that if people have an awareness of the concept decision-making process, including knowledge of dependence factors and intrinsic conflicts, they are less likely to become victims of circumstances. They can ‘take charge’ over their own decision-making process (Nutt, 1999), and try to mitigate negative impact of psychological traps (Keeney, 2004). Since few people are educated in decision making (Keeney, 2004; Riabacke, 2007), the author suggests that just knowing about what is influencing the process will improve it, i.e. having a meta-knowledge. Implications for practice can be summarized with a quote from Hammond et al. (1998, p.58): “forewarned is forearmed”, meaning that awareness and understanding of
one’s own decision-making process are a good start for improvement of the overall decision-making process.

*Ask questions*. Questions are regarded as a powerful tool both by respondents and in literature (Menzel et al., 2007; Purser, 1992), and questions was also frequently observed in the empirical studies. Since there are many aspects that influence concept decisions which are not consciously taken care of in the present concept decision-making process, the author recommends asking questions regarding these otherwise neglected aspects. For example, Rausch (2003) proposes an eight-question model (addressing goals, communication, participation, competence, satisfaction, cooperation, norms and reviews) to guide the decision maker, instead of leading directly to specific conclusions.

*Provide visualizations*. To visualize the process can help to handle the intrinsic conflicts in the concept decision-making process, e.g. to enhance the common understanding in the organization regarding the process and what criteria to use for concept evaluation. Process models can also encourage integration and coordination (Engwall, 2003a), and such visualizations should be provided close to people in their daily work, and be continuously updated (Olausson and Berggren, 2011). Further, visualizations of solutions and technical data can enhance mediating complex information (Montoya-Weiss and O’Driscoll, 2000), something that is needed in time-pressured concept development, and especially in the agenda-based meetings studied.

*Provide vision as guidance*. The concept decision-making process was concluded to be a web of interconnected activities, including major and minor decisions on many levels. Therefore, it is important to provide guidance for all the daily decisions and trade-offs that the actors have to make, and here a strong and well-communicated vision could guide the actors in the concept phase (McAdam and McClelland, 2002; Menzel et al., 2007; Santa et al., 2011; Spanjol et al., 2011). This, however, requires a lot from the top management level: a combination of official documents and walk-the-talk actions.

*Ensure reflections*. An all-pervading theme in the appended papers is a need for actors to reflect on the decisions and decision process, in order to improve the concept decision making. It is found in this research that an unreflective decision-making process is less successful for the organization, exemplified by items consuming valuable time when recurring in meetings without any value added between the occurrences (Paper E). Therefore, the author suggests that more reflective decisions, in early phases of product development, will directly enhance the decisions, but most of all – will build a long-term capability to make better decisions in the innovation process. Reflection is a useful tool, especially in early development phases, and learning does not happen unless knowledge is developed (Hammed et al., 2011; Purser, 1992; Wickelgren, 2005). Reflections can be made both as an individual and in a group, where feedback can be used as a tool for learning (Argyris, 1976; Verganti, 1997). Hence, this requires creating space for making reflections. This research will not give any recommendation on what method for concept evaluation to use, but instead it emphasizes the use of a method as a tool to create possibilities for reflections and discussions. Further, reflections can be used as a way to acknowledge, and cope with, the omnipresent fuzziness, since that is a basic characteristic of this phase, and with the likelihood that things are going to change (Jönsson, 2004). However, actors in the process face a challenge regarding when just to trust gut feeling and simplify the situation, and when to stop and reflect (Posavac et al., 2010).
Finally, the design methodology literature shows a pattern that is in line with the author’s suggestions. There is, according to Kopecka et al. (2011), a shift away from perspective design process models towards a new generation of descriptive, context-aware models. The new generation of design process models emphasizes the need for reflection as a means of learning from design experience, and of creating moments for the designer to critically review the own work (Kopecka et al., 2011).

5.3.2 A proposed model for improving concept decision making in practice

In order to support people in organizations to handle uncertainty and complexity, and to make better concept decisions, a model to improve the concept decision making in practice was conceptualized and presented in Paper F. Such an approach should, according to previous research: combine formalized and quasi-formalized process, address the interplay between individuals and organizations, be holistic, use visualization, and use participative reflections (Argyris and Schön, 1996; Martinsuo and Poskela, 2011; Olausson and Berggren, 2010). The presented model, which utilizes the key elements discussed in previous section, includes eight modules (Figure 5.3): Seminars, Coach Teams, Coach People, Visualize the Process, Visualize Content of the Process, Checklist Start of Concept Work, Battery of Questions, and Align Every Day Decisions.

![Figure 5.3: Model for improving concept decision making](image-url)

<table>
<thead>
<tr>
<th>M1 Seminars</th>
<th>M2 Coach Team</th>
<th>M3 Coach People</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance knowledge and awareness of decision making</td>
<td>Give specific feedback to a team</td>
<td>Give specific feedback to an individual</td>
</tr>
<tr>
<td>Reach many people</td>
<td>Follow over time</td>
<td>Follow over time</td>
</tr>
<tr>
<td>Easy to arrange</td>
<td>Task can be rotated in the team</td>
<td>Encourage reflections</td>
</tr>
<tr>
<td><strong>Create meta-knowledge and awareness</strong></td>
<td><strong>Encourage reflections</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M4 Visualize the Process</th>
<th>M5 Visualize the Content of the Process</th>
<th>M6 Checklist Start of Concept Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarify the process</td>
<td>Clarify decision foundation</td>
<td>Ensure best possible start of concept work</td>
</tr>
<tr>
<td>Create common understanding</td>
<td>Mediate complex information</td>
<td>Also cover more informal aspects in the process</td>
</tr>
<tr>
<td><strong>Provide visualization</strong></td>
<td><strong>Provide visualization</strong></td>
<td><strong>Ask questions</strong></td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>M8 Align Every Day Decisions</th>
<th>M7 Battery of Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guide daily decisions</td>
<td>Ensure that important aspects are considered</td>
</tr>
<tr>
<td>Alignment with company’s vision</td>
<td>Also cover more informal aspects in the process</td>
</tr>
<tr>
<td><strong>Provide visions as guidance</strong></td>
<td><strong>Ask questions</strong></td>
</tr>
</tbody>
</table>
DISCUSSION

The model was developed in collaboration with practitioners. In Paper F the modules were evaluated regarding usefulness and feasibility to implement in an organization, together with presenting the successful tests of the modules **Seminars** and **Coach Team** in hands-on concept development work in the case company. Each module can be deployed individually; however, modules are preferably combined in a way that suits the specific organization. Applying all the modules cannot, of course, guarantee good outcomes from the decision process, corresponding to Howard’s (1996) distinction between a good decision and a good outcome. But applying the model will most definitely raise the possibility for reaching better decisions. The total set of modules is designed to address individuals as well as teams, which is a necessity due to the multi-faceted nature of the concept decision-making process, in line with Bharadwaj and Menon’s (2000) recommendations to address both individual and team level. Some modules are meant to support daily hands-on work, and some of them are to be used for education and training, externally to the actual process. In addition, some modules are meant to be used in iterations between the process and externally to the process. Further, it should be commented that the modules cover both tangible support, such as checklists and templates, and more intangible elements such as education and visions.

Since the purpose of applying the modules in an organization is to create improvement, it is central to evaluate the impact of each module, as application in practice will probably be made module by module. In such an evaluation the author recommends to distinguishing evaluating the activities performed and the actual effects they have. The first category is easier to evaluate than the latter. Nonetheless, the evaluation should be twofold in order to capture both that initiatives are made, which may be a challenge in itself within a real-life setting, as well as the effect aimed for. For example, Seminars can be evaluated using the number of occasions and participants as indicators of implementation, and by a qualitative evaluation (a while after the seminar) if participants have used what they learned in the seminar, as an indicator of effect. However, these indicators should be designed specifically to suit both the task and the organization, and in Table 5.1 some suggestions are given for each module in order to give further support for improving concept decision making in an organization.

<table>
<thead>
<tr>
<th>Modules</th>
<th>Indicators of implementation</th>
<th>Indicators of effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 Seminars</td>
<td>Number of sessions/participants</td>
<td>More reflective questions are asked</td>
</tr>
<tr>
<td></td>
<td>Experienced rise of knowledge</td>
<td></td>
</tr>
<tr>
<td>M2 Coach Teams</td>
<td>Number of coached teams</td>
<td>More reflective questions are asked</td>
</tr>
<tr>
<td></td>
<td>Number of feedback occasions</td>
<td></td>
</tr>
<tr>
<td>M3 Coach People</td>
<td>Number of coachees</td>
<td>More reflective questions are asked</td>
</tr>
<tr>
<td></td>
<td>Number of feedback sessions</td>
<td></td>
</tr>
<tr>
<td>M4 Visualize the Process</td>
<td>A visualization is present</td>
<td>Members of the organization to evaluate raised awareness as experienced</td>
</tr>
<tr>
<td></td>
<td>Number of changes in model</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(changes = signs of interactions)</td>
<td></td>
</tr>
<tr>
<td>M5 Visualize Content of the Process</td>
<td>Spider charts used</td>
<td>Experienced quality of the decisions</td>
</tr>
<tr>
<td></td>
<td>Red/Yellow/Green used</td>
<td>Reflective questions asked</td>
</tr>
<tr>
<td>M6 Checklist Start of Concept Work</td>
<td>Such discussions have taken place</td>
<td>First Time Through (FTT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More aspects are taken care of</td>
</tr>
<tr>
<td>M7 Battery of Questions</td>
<td>Content of checklist broadened – and used</td>
<td>More aspects are taken care of</td>
</tr>
<tr>
<td>M8 Align Every Day Decisions</td>
<td>Interpretation of the brand?</td>
<td>Agreement on: best for the company?</td>
</tr>
<tr>
<td></td>
<td>Less contradictive sub-targets</td>
<td>Smoother process</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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Table 5.1: Suggested indicators of implementation
This work was grounded in an assumption that tools and parameters used for steering the decision-making process in early product development phases today do not cover all aspects that influence the actual decision-making process in industrial settings. Therefore it is important that the approach presented here is not falling into the same traps as the ones for which the author earlier criticized the currently available support. By emphasizing qualitative reasoning and the need for reflection, addressing engineering environments, the author aims to contribute with a holistic approach covering perspectives such as individual/team, inside/outside the process and tangible/intangible support. The modules could be further developed in future research studies. Implications for practice are to consider how the modules should be applied in the specific organization.
6 Conclusions and implications for practice

This research has investigated concept decision making through in-depth studies in complex product development. The purpose was to build knowledge around how experienced difficulties in concept decision making could be explained and, moreover, how they can be managed, aiming to enhance both theory and practice. This thesis contributes with an exploration of industrial concept decision making as well as identifying how concept decision making can be improved, and therefore implications for practice is included here.

Given the context of concept decision making in development of complex products, the following conclusions could be drawn, providing a deeper understanding of concept decision making:

* Besides the conventional definition of a ‘concept’ (an idea) it was also found that ‘concept’ could describe a certain state of mind: being prepared to experience “that anything can change”.
* The concept decision process is a web of interconnected activities, embedded in the concept development process, with involvement of actors on different hierarchical levels.
* The process is influenced by several dependence factors, both formal and informal:
  * Prescribed support available does not, either in literature, or in the case company, handle all factors that actually influence concept decisions. Hence, there is a need to improve support methods so that they cover more aspects.
  * The identified dependence factors were: Project and Product Request, Supporting Structures and Routines, Individual Competence and Driving Forces, Teamwork and Company Culture, and Contextual Circumstances.
* In concept decision-making meetings, defining working assumptions (selecting a main track to focus on) and asking questions were identified as elements used to reduce equivocality and uncertainty, and drive the decision process forward.
  * Three different genres of questions were identified, posed by people in different roles, with different purposes: *elucidating*, self-enlightening, and *argumentative questions*.
  * Using agenda-based meetings has implications for concept decision making, since such a fragmented agenda, and the nature of concept phases may be in conflict.
* The discussion regarding a theory/practice gap should be extended to include the entity of companies’ internal instructions. How working procedures are disseminated in organizations should also be considered.
* Challenges in the concept decision-making process are:
  * To develop alternative solutions, instead of iterating one main-track solution.
  * When alternatives are developed – to compare them properly.
  * To achieve *compatibility before completeness*, meaning that compatibility between product systems must be met before the system solutions are completely developed.
Four conflicts, intrinsic in the concept decision process, which indicate underlying causes of the difficulties in managing the concept decision making, are identified. These conflicts are omnipresent due to product and organizational complexity, and have to be handled in the daily work:

- Understanding of the overall development process as iterative or stepwise.
- Developing satisfying or optimized solutions.
- Using defined or interpreted criteria when comparing solutions.
- Composing a complete car from different systems solutions, prioritizing project targets or long-term system targets.

In order to improve concept decision making, five key elements to utilize are identified:

- Create meta-knowledge and awareness regarding what influences the process and the actors in the process.
- Ask questions to ensure that aspects previously neglected, are considered.
- Provide visualizations to enhance understanding of both process and solutions.
- Provide vision as guidance to help everyday decision making and trade-offs.
- Ensure reflections since there is a need for actors in the process to reflect on their own decision-making process.

6.1 Implications for practice

This research has been conducted with a practice-centered view, aiming also to contribute to product development practice, and from an industrial perspective the following contributions are identified:

- A key is to create room for reflections in the regular operations. Through reflections, knowledge required for learning can be created, improving an organization’s decision-making competence.
- Raise the awareness of what might influence the decision making (individual as well as organizational decision making).
- Acknowledge the fuzziness and uncertainty, and learn how to handle them since they are basic characteristics of concept decision making, and the fact that changes certainly will occur.
- Reflect on the design of decision-making meetings in early development stages.
- Reflect on the role of the internal instructions, e.g. how they are developed and implemented. Further, an organization can identify what internal support is actually used in the process, and can utilize this as a tool for improvement.

To address identified challenges and intrinsic conflicts, a model for improving concept decision making in practice was developed, evaluated and tested. The model includes a number of modules designed to be applicable and to make an actual change within a product-developing organization:

- Included modules are: Seminars, Coach Teams, Coach People, Visualize the Process, Visualize Content of the Process, Checklist Start of Concept Work, Battery of Questions, and Align Every Day Decisions.
- The total set of modules is designed to cover different perspectives such as individual/team, inside/outside the process and tangible/intangible support.
- Each module can be deployed individually, but they are preferably combined in a way that suits the specific organization.
CONCLUSIONS

In-depth studies were conducted in an automotive company, which meant that the studies had product development of complex products as a context. The research work has focused on the system level, i.e. the operations of an engineering department, responsible for a part of a car, working in parallel with other engineering departments. The results mainly address concept decision making in established product development organizations, developing complex products. Due to the in-depth nature of the research conducted, the transferability is somewhat limited. However, the author asserts that the results presented here most definitely provide valuable and useful insights, and elucidate relevant phenomena within decision making in early product development phases, interesting for practitioners from other companies as well as researchers in the area. In particular, the findings are suggested to be interesting for product development companies that experience challenges in facing early development phases, as well as product and organizational complexity.

6.2 Suggestions for further research

Interesting directions for further research identified during the research project were:

- In-depth studies on how to form prescriptive models for concept decision making, including both mediating vision and goals, and supporting the operative level. How should the flexibility needed be included in order to be adaptable to diverse contexts?
- Develop the model for improving concept decision making presented above and further elaborate on how to improve concept decision making in practice, reaching more understanding of the interface of mutual interdependence between developed support methods and their actual application.
- Extend the empirical base beyond the context used in this project. Cross-case studies could be conducted in order to improve generalizability of the findings.

6.3 Reflections on the research process

The closeness to the studied organization has been a strong influence in the research project. It has been beneficial to follow an organization closely, and thereby to get critical insights that otherwise would not have been detected. A potential drawback is of course a risk of not being able to create the necessary distance in order to critically scrutinize the organization of which the author herself is a part. Therefore the author has tried to distinguish the empirical material from the interpretations made. Due to closeness and access to the researched organization the author is convinced that the research findings achieve the validity sought for.

A shortcoming of this type of research is the issue of proving any direct effect of the conducted research. This is mainly because the research topic in itself is complex and has long-term aims, and since specific effects are difficult to separate from everything else that influences an organization. However, due to the continuous dialogue with practitioners in the studied organization, Verification by Acceptance (Buur, 1990) has been used to a large extent to verify and validate the research results. Further, a combination of different methods and sources of data has increased the trustworthiness of the research studies, where also the collaborative nature of analysis and writing procedure has contributed. Finally, summarizing the effort made in the research project, one cannot, as a research student, omit to acknowledge the overall learning process of conducting research studies, continuously improving data gathering, data analysis, and writing skills.


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