Value balancing method for product development

- A case study at Volvo Car Corporation -

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Abstract

The study aims to develop a method that provides Concept Engineering Unit at Volvo Car Corporation (VCC) with reflection on how cost, technical characteristic, and customer requirements effects the end-product. The purpose of this thesis is to develop a method that supports value balancing of customer requirements and costs in the concept phase of the product development process at VCC.

The study has been performed as a case study at VCC in Gothenburg. It was done at the Concept Engineering Unit, which is responsible for managing the different development units at VCC during the concept phase in order to achieve several requirements.

The theoretical background covered: value based decision making, communication and collaboration within companies, the impact and efficiency of decision support tools, customer satisfaction theory, cost consideration and implications of product platforms on the product development process. The explorative study covered the product development process, cost calculation systems, platform usage, cost of change and attribute classification at VCC.

The study resulted in a proposed Value Balancing Method that contains the following parts: Main QFD matrix, Value Index chart, Critical Attributes and Systems and a Modularity Matrix.

The information from the Value Balance Method can be used to study which technical systems that need to be functionally improved and which systems that need cost reduction effort in order to achieve value balanced products. Moreover, the Value Balance Method provides valuable information of which systems that should be platform systems and which that ought to be product specific systems. Moreover, the Value Balance Method identifies attribute areas that need extra management attention in order to enable a successful product development.

The Value Balance Method provides general data at an overview level to support the product development team in the holistic and complex situation of product development process at VCC. Further the method will enable collaboration and communication in cross-functional product development teams at VCC. Further work needed for the Value Balance Method is first of all incorporation of the data from the ongoing study of customer ranking of attribute at VCC. The method also needs to be tested in order to improve its' accuracy and validity.

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Special thanks to Jonas Söderqvist for great teamwork.

Göteborg, 27 May 2004

Carl Stenbeck Johan Svensson

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Abbreviations

DA	Differentiating Attributes
EB	Description of Characteristics (Egenskapsbeskrivning)
FKB	Functional Requirement Description (Funktionskravsbeskrivning)
FMC	Ford Motor Company
FTLE	Facilities, Tooling, Launch, Engineering
M	Modified part
NPV	Net Present Value
P	Reused part
PAP	Product Attribute Profile
PPL	Product Planning Department (Produktplanering)
PSS	Product Structure Systems
QFD	Quality Function Deployment
U	New unique part
VCC	Volvo Car Corporation
X	New part

1. Introduction

This chapter gives an overview of the problem background and argues the relevance of the study. The purposes of the study and research question with sub questions will be presented. Further, this chapter provides the limitations and an outline of the study, the study's objective and a discussion of interested parties.

1.1. Problem background and motivation of study

In today's intensely competitive environment firms must secure a high customer satisfaction in order to survive. Hanan and Karp (1989) state: *"Customer satisfaction is the ultimate objective in every business: not to supply, not to sell, not to service, but to satisfy the needs that drive customer to do business".* More and more firms use satisfaction ratings as an indicator of the performance of products and services and as an indicator of the company's future since a high level of customer satisfaction leads to a high level of customer loyalty. A high level of customer satisfaction has also been shown to reduce price elasticity, as satisfied customers are willing to pay more for high quality products and services (Matzler and Hinterhuber, 1998).

A diversified set of demanding customers requires the ability to adjust products to a varied set of customer requirements. It is no longer possible to act on large markets by developing and mass-producing one product at a time. In order to compete on the market firms must tailor their products to the need of the individual customer (Robertson and Ulrich, 1998). Further, the challenge of product development in technological advanced business has moved from achieving product functionality to efficiently fine-tune the functionality of the product to the changing requirements of the customer. Pressured by the need to respond quickly and to offer complex product lines to satisfy rapidly changing and varied customer requirements, companies are faced with the needs to develop ways to introduce products more quickly and efficient than before (Iansiti, 1995).

Further, the development of new products is rewarding and necessary to maintain a healthy organization. This has been shown in numerous articles referred to in Hsaio (2001). Booz et al. (1982) showed that over a five-year period 28% of 700 studied companies' total growth derived from products with less than five year on the market. Duer (1986) found that 35% of firms current revenue was derived from products that where not on the market 10 years ago.

Wind et al. (1990) found that 25% of current sales were derived from new products introduced in the last three years.

Product changes have been shown to increase considerably later in the product development process. Therefore firms must strive to make the right decisions as early as possible (Bergman and Klefsjö, 2001). The increase of relative cost of change over time is showed in Figure 1.

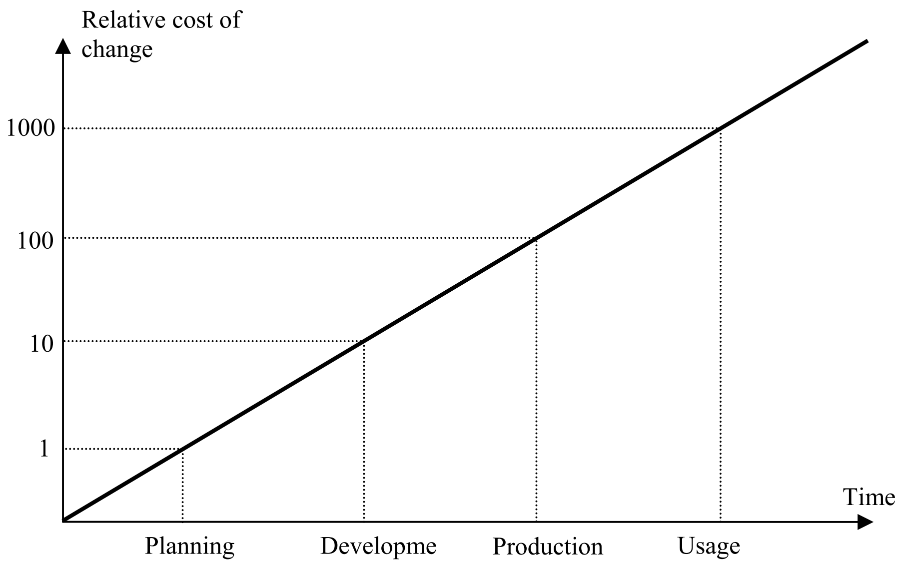

Figure 1 The increase in cost of change (Bergman and Klefsjö, 2001)

Further, the importance of early cost considerations when developing new products and how early design decisions affect the products final total cost has been studied in a number of studies. Cooper and Slagmulder (1997) argues the relevance of managing costs early and states that as much as 90-95% of a product's costs are designed in the product, and thus are not possible to affect once the product base design is determined. Ask (1999) refers to Berliner and Brimson (1988) who found that 70-90% of a product's cost is locked-in by early decisions. Ansari and Bell (1997) illustrate the costs' dependence on early decisions by describing the relationship between committed costs and incurred costs. This relationship is visualized graphically in Figure 2.

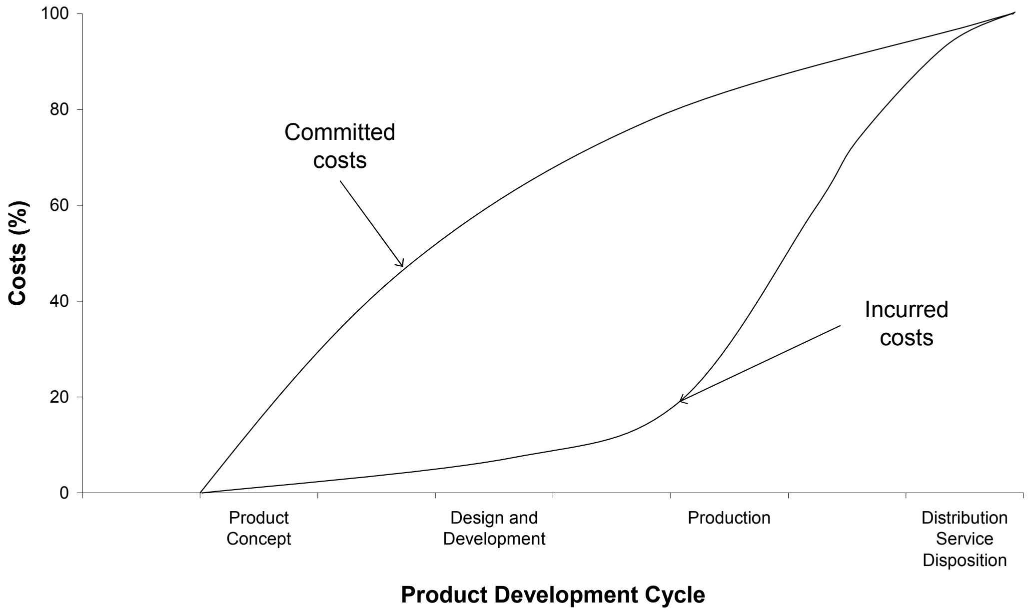

Figure 2 Comparison of Committed and Incurred Costs (Ansari and Bell, 1997)

From Figure *2* it is obvious that the majority of costs are committed at the design stage while most of the costs are incurred at the production stage. Further, Shehab and Abdalla (2001) states that 70% of the production cost of a product is determined during the conceptual design stage. However, the design phase itself accounts for only 6% of the total development cost. Therefore, managing the cost of future products is the only way to ensure that future products will be profitable (Ansari and Bell, 1997).

The transformation from being a producer of mass-standardized products to a producer of customized tailor made products that satisfy individual customer needs, in combination with a demand of new products leads to shorter product life cycles and decreasing product volumes (Koufteros et al., 2002). Therefore, many firms seek new ways to accomplish economies of scale by using the same parts or sub-systems for different products. Firms adopt this concept in order to minimize variety in parts or sub-systems in which customer do not value variety (Sudijanto and Otto, 2001). This is how the platform strategy has emerged. The platform strategy is characterized by the use of common product architecture with shared subsystems and standardized interfaces (Meyer and Mugge, 2001). Platforms are used by companies to increase variety in the marketplace while retaining a low variety in the firms operations (Fisher et al, 1999). Further, by using platforms companies can increase the flexibility and responsiveness of the manufacturing process and thus decrease both product development cycles and costs (Robertson and Ulrich, 1998). The downside is that product development teams are limited in their choice of technical solutions due to the pre-determinative characteristics of the platform strategy.

To conclude, products must be designed so that they quickly deliver the quality and functionality that are demanded by customers while generating the desired level of profits for the firm, thus strive towards producing value-optimized products. Value is typically expressed as degree of importance to a customer. In order to achieve value optimization there is a need to manage the product development process. Because of the cost lock-in effect, firms need to visualize this correlation early in order to minimize the number of late changes in the product development process.

1.2. Problem definition

Products must be designed so that they deliver the quality and functionality that are demanded by customers while generating the desired level of profits for the firm, thus is value-optimized (Cooper and Slagmulder, 1997). Research has shown that the ability to manage product development is not only a function of effective planning at the strategic level and strong project management and that success also is linked to routines and approaches for technology selection, evaluation and adaptation (Iansiti, 1994). In firms with well-developed platform strategies value-optimizing products are challenging due to the many pre-determined variables. The product development process is integrated with several internal processes, such as purchasing, marketing, and service. It is also depend on many external stakeholders and their specific activities. In this environment, with short lead times and parallel process, it is obvious that product development is a rather complex process (Nilsson, 2004).

In order to be effective the product development process needs effective decision support tools (Zhao et al., 1993). Moreover, studies has shown benefits of using tools and techniques for improving the product development process but there is a need of improved assessment of tools and techniques in order to reduce the gap between the rhetoric and the reality of process improvement (Maylor, 2000).

A company with the characteristics described earlier is Volvo Car Corporation (VCC), see Chapter 2.3 for a presentation and motivation of the choice of company. At this VCC a need is identified for a new or adjusted existing method that provides product development teams with information about how different factors affect the products future success. In order to value-optimize products, the method needs to focus on the inter-relationships between customer requirements and technical attributes and makes cost a design input.

1.3. Research question

In order to develop a method for the problem described above, the study involves identifying cost and customer requirement data the makes the method reliable and valid. The study will deal with the circumstances with inherited and shared subsystems that exist in firms using platforms. The study will also provide an analysis of these data in order to determine the method's ability to be adopted into existing accounting and marketing processes at VCC. Further, the study aims to provide guidelines for implementing the method into VCC' product development process. This includes an analysis of which functions that needs to be involved in the work of using the method.

1.4. Objective

The study aims to develop a method that provides product development teams at VCC, and firms with the characteristics described in previous chapters, with reflection on how cost, technical characteristic, and customer requirements effects of the end-product. The goal is to develop a method utilizable for achieving a value-optimized balance of the products. Further, the goal is to develop a method that makes effects caused by changes, elimination and addition of sub-systems and new features visible to the product development team.

1.5. Purpose

The purpose of this thesis is to develop a method that supports value balancing of customer requirements and costs in the concept phase of the product development process at VCC.

1.6. Limitations

This thesis will not provide analysis of how to technically allocate customer requirements to technical systems. This technical analysis part of the development of the method will be provided by Jonas Söderqvist, Chalmers University of Technology. Söderqvist has performed his master thesis for a mechanical engineering degree at VCC simultaneous as the writers of this thesis. Söderqvist work includes a technical allocation of features to technical systems.

1.7. Potential Contributions and Interested Parties

Several research projects and thesis works have been performed at VCC and aimed at improving cost considerations and incorporate customer satisfaction in the daily work in the concept design phase of the product development process. But many of the proposed improvements have not been implemented due to lack of implementation procedures recommendations and adaptation to current routines at VCC. This study aims at developing a concrete method that should be ready to be adopted by Concept Engineering Unit and fit existing structures and routines at VCC. If the method can be successfully implemented at Concept Engineering Unit it might create an interest for implementation at other departments at VCC with similar need of early cost and customer requirements considerations. The theoretical framework for the method will be generalizable to other companies in other business but due to the need of careful and thoroughly adaptation to current routines and procedures this thesis's conclusions in total will not be generalizable.

1.8. Thesis Outline

The remaining parts of the thesis will be structured as follows:

- Chapter 2 - thoroughly presentation of research methodology, including a discussion of validity and reliability of the thesis
- Chapter 3 - previous academic findings on the topic
- Chapter 4 - theoretical framework for a preliminary method
- Chapter 5 – Presentation and discussion of the main study
- Chapter 6 – Analysis of the results
- Chapter 7 – Proposal of a method
- Chapter 8 – Conclusions and discussion of the thesis's findings. Recommendations for further work

2. Research methodology

This chapter outlines different aspects on research methodology and provides a thoroughly discussion of the arguments for this study's research methodology and possible optional methodologies. The chapter further provides systematically information of how the main study was performed and gives an overview of the studied case object and a discussion of the study's validity and reliability. Finally, this chapter provides an overview of the research process.

2.1. Methodology overview

Questions on methodology are focused on the specific ways to examine and understand our world. Ontology refers to the true form and nature of reality. Epistemology, the study of the foundations of knowledge, examines what kind of knowledge we can obtain from this reality (Frankfort-Nachmias and Nachmias, 1996).

There are two main approaches used for researching in social science: positivism and hermeneutic. The choice of main approach forms and legitimates the ground rules for the research. The positive approach has its origins in the natural sciences where experiments, quantitative measuring and logical reasoning are meant to give a general representation of reality. These studies are formalized and well structured and a high level of control from the researcher characterizes the method. The hermeneutic approach on the other hand, takes a more holistic view directed towards understanding and interpretation and is less structured (Lundahl and Skärvad, 1992).

Moreover, the different approaches to handle the relationship between theory and reality distinguish research methods. Three main differences exist and are commonly referred to as: deduction, abduction and induction (Patel and Davidson, 2002). The differences between these three are illustrated in Figure 3.

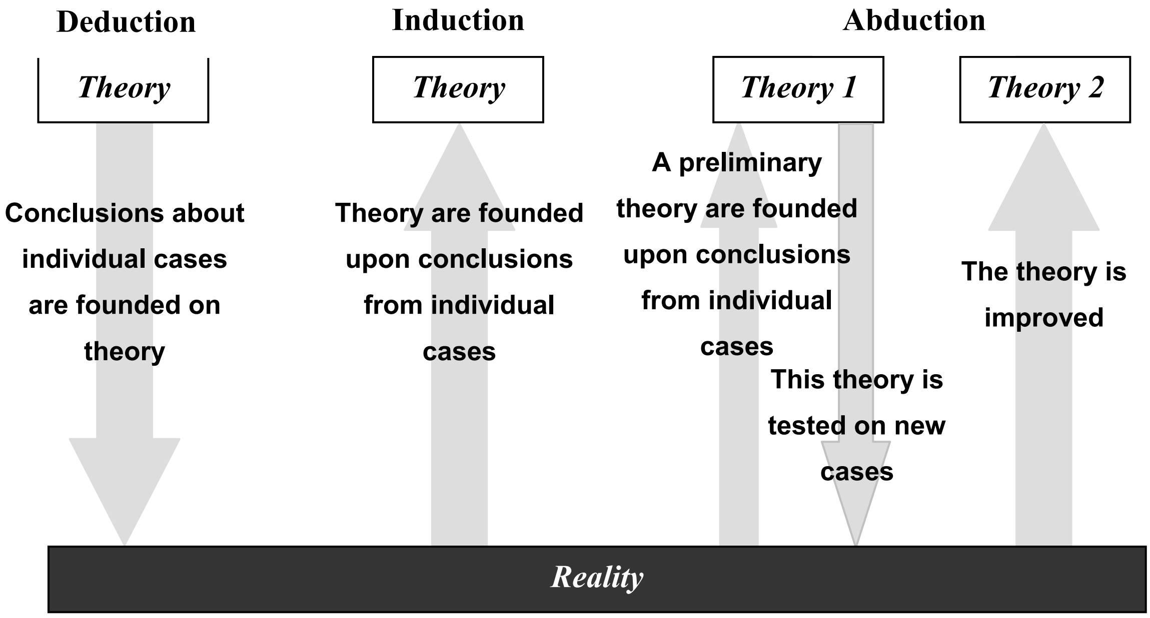

Figure 3 The relationship between theory and reality (Patel and Davidson, 2002)

2.2. Choice of methodology

This study takes the positive approach to research, but with influences of the hermeneutic approach. The purpose is to develop a value balancing method for the product development process, which implies finding a structured way to work with holistic multidisciplinary functions. Therefore qualitative data have been used as empirical data. Moreover, this study applies an abduction approach to the relationship between empirical data and theory. In order to capture the holistic interconnections between customer requirements, technical systems, financial data, and platform dependent features at the same time as enabling interplay between different corporate functions, the study firstly uses a somewhat simultaneous method of handling theory and empirical data for developing a preliminary method.

The purpose of this study is to develop a method for value balancing in the product development process and therefore it could be argued that to some extent process change will come from this study. Since the authors of the study will develop and give guidelines for implementations of the method, action based research method is applicable (Andersen, 1990). Change oriented action based research is characterized by that the researcher performs concrete actions which narrows the distinction between theory and action (Andersen, 1990).

Research based on a case study is preferable when studying present and contemporary events and when it is impossible to control or manipulate relevant variables. A case study is based upon direct observations and systematic interview (Merriam, 1988). A case study is according to Yin (2003) relevant when *"... a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control."* Moreover a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. Since these conditions are present at Volvo Car Corporation a case study method is an efficient research methodology.

2.3. The case study

In order to give the reader a brief overview of the environment in which this case study was performed a presentation of the company and the specific unit the researcher studied are presented. Extensive research in academic fields nearby the academic fields this study addresses has previously been performed at Volvo Car Corporation and therefore results from these studies are described later in this section.

2.3.1. Volvo Car Corporation

Volvo Car Corporation is since 1999 wholly owned by Ford Motor Company (FMC). Along with Aston Martin, Jaguar and Land Rover, VCC is part of Ford's Premier Automotive Group (PAG). Volvo Car Corporation and Volvo Group own the Volvo brand in a joint trademark company.

Volvo Cars sales and service network covers about 120 countries, comprising some 2,000 dealers. Much of the network is composed of independent companies working with Volvo Car Corporation as a business partner. Volvo Cars' four largest markets are USA, Sweden, Germany and UK and VCC has major plants in Sweden and Belgium.

Volvo Car Corporation's headquarter and other corporate functions are based in Gothenburg, Sweden. President and CEO is Hans-Olov Olsson. VCC's total amount of employees was 27 990 in year 2002 (www.volvocars.com).

2.3.2. The Concept Engineering Unit at Volvo Car Corporation

The study has been performed at the Concept Engineering Unit of the R&D department at Volvo Car Corporation in Gothenburg. The Concept Engineering Unit works in the Concept phase of the product development process with managing the different development units. The target with the Concept stage is to give a total business offer on the car concept, including the industrial structure. This means to define the product and the manufacturing processes regarding commonality, design, attribute profile, main dimensions, architecture, and system solutions. As discussed in the introduction a large part of the product cost are committed in the concept stage which makes the Concept Engineering Unit a suitable and interesting unit to study.

2.3.3. Previous research at Volvo Car Corporation

Over the years, Volvo has put a lot of effort to investigate models to improve the product development process. Andersson and Vigetorp (2000) formulate a complementary model for product development management at Volvo Car Corporation focusing on proactive decision making based on product attribute, target costs, and product development time. The model has not been implemented at Volvo Car Corporation.

The concepts of target costing management and its effects on the product development process at Volvo Car Corporation have been investigated in several academic papers and thesis at Volvo Car Corporation. Bertilsson, Thollonen, and Vigetorp (1999) investigate the requirements for Volvo Car Corporation to implement target costing management in the product development process. The authors conclude that in order to succeed with target costing management the top management needs to show an active support for the strategy to support the necessary organizational changes. Further, knowledge about the strategy needs to be distributed across the company and lastly, the assignment of a process owner to the target costing process is essential for the success of the strategy. Omerovic (1998) reached similar findings and states that a successful implementation of target costing at Volvo Car Corporation requires education and management support. Eklund and Hedberg (1998) investigate the theoretical foundation of target costing and its practical implication if implemented in the product development process at Volvo Car Corporation. The authors argue the academic accuracy of target costing by referring to Pareto Optimum but conclude that the main obstacle with the usage of target costing is how to avoid disturbance when transforming customer value into technical data. The authors however conclude that target costing would be an effective method at Volvo Car Corporation that would improve analysis of customer value adding.

Storm (1998) discusses processes and tools within the Volvo Value Management Process. The author evaluates these tools and concludes that Volvo Car Corporation could find new solutions from this set of tools to measure customer value and to decompose the target cost for a car. Further, the author identifies a need for refinement in methods and an action plan for implementation of new tools to support the value decomposition process.

Ask (1999) discusses management accounting in product development and evaluates Value Engineering and Target Costing efforts at Volvo Car Corporation. The author recognize a need for a systematic methodology and practical tools that enables to transform the academic theories into work routines affecting the daily work in the product development process.

Research at Volvo Car Corporation by Sten-Olov Gustavsson, former associate professor at Chalmers University of Technology, led to the creation of a modularity matrix presented in Figure 4. The technical systems in the matrix are placed according to their degree of customer value and cost complexity. The number and names of technical systems do not correspond to the number and names of the technical systems currently used at VCC.

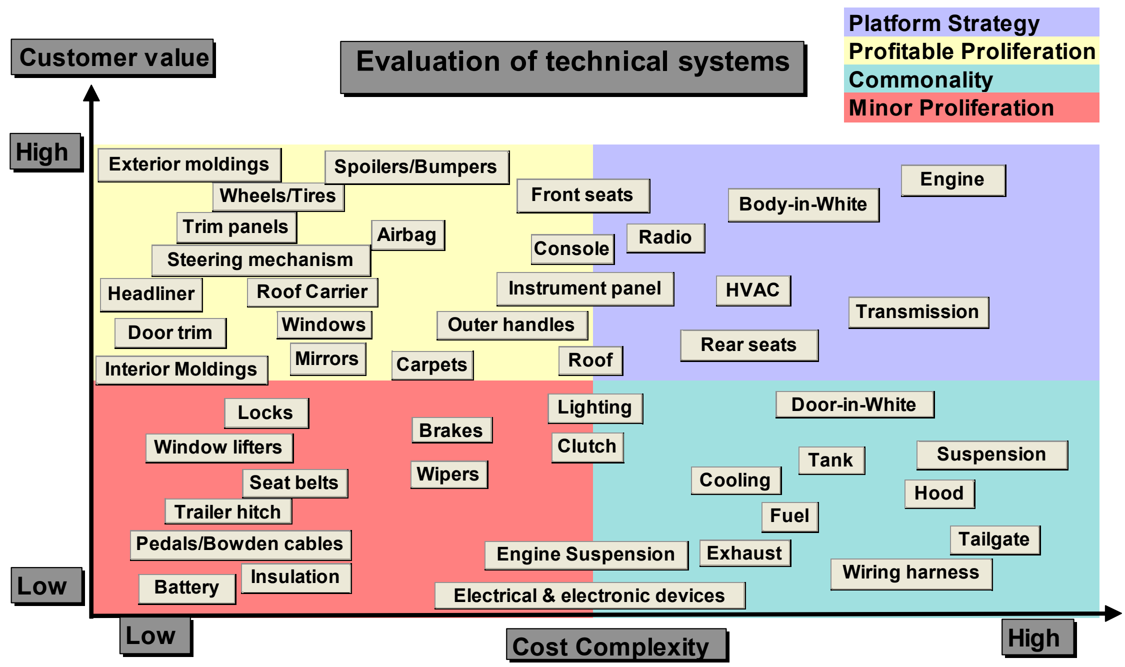

Figure 4 Technical System Portfolio Matrix

VCC has not implemented the changes and recommendations suggested in the previous research discussed above. The reason for this is likely to be that the gap between academic and practical issues are to wide, i.e. the models have not be developed with focus on fitting the existing procedure and routines at VCC. In line with Maylors (2000) discussion of the need of improved assessment of tools and techniques in order to reduce the gap between the rhetoric and the reality of tools like this thesis will focus on delivering a method that is ready to be implemented at VCC.

2.3.4. Why Volvo Car Corporation?

Volvo Car Corporation acts in an industry characterized by complex products with long product development cycles. Platform strategies are used extensively in the automotive industry. Further, although the implementing has been difficult, previous research at Volvo Car Corporation has identified the company as suitable for implementing new methods and tools for improving the product development process. Moreover, Volvo Car Corporation has shown an extensive interest in developing new methods, which gives the researchers unique access to relevant data and people. The combination of these factors makes Volvo Car Corporation an interesting case study from a academic and research point of view.

2.4. Research Process

A schematic picture of the work flow and output from the research is shown in Figure 5. The research started with a definition of the general problem and the limitations of the study. This was done in collaboration with the Concept Engineering Department at VCC.

In the next phase a preliminary interviews was performed and an explorative preliminary literature study began. These two activities were performed in parallel because of the need of a concrete problem definition and to identify which research areas that needed to be studied and examined in the forthcoming literature study. These two processes are done simultaneous and will therefore influence each other. After defining the problem an analysis of relevant methodology options was performed. This resulted in a choice of methodology for this study.

An extensive literature study was performed after defining the problem and the methodology of this thesis. In the literature study the research areas identified in the pre study was thoroughly examined.

The literature resulted in the creation of a theoretical framework. After this phase the main study begins with interviews and an explorative study of VCC. The results from the main study are then analysed and the proposed method is designed. The model is then discussed and the validity and reliability of the research is questioned.

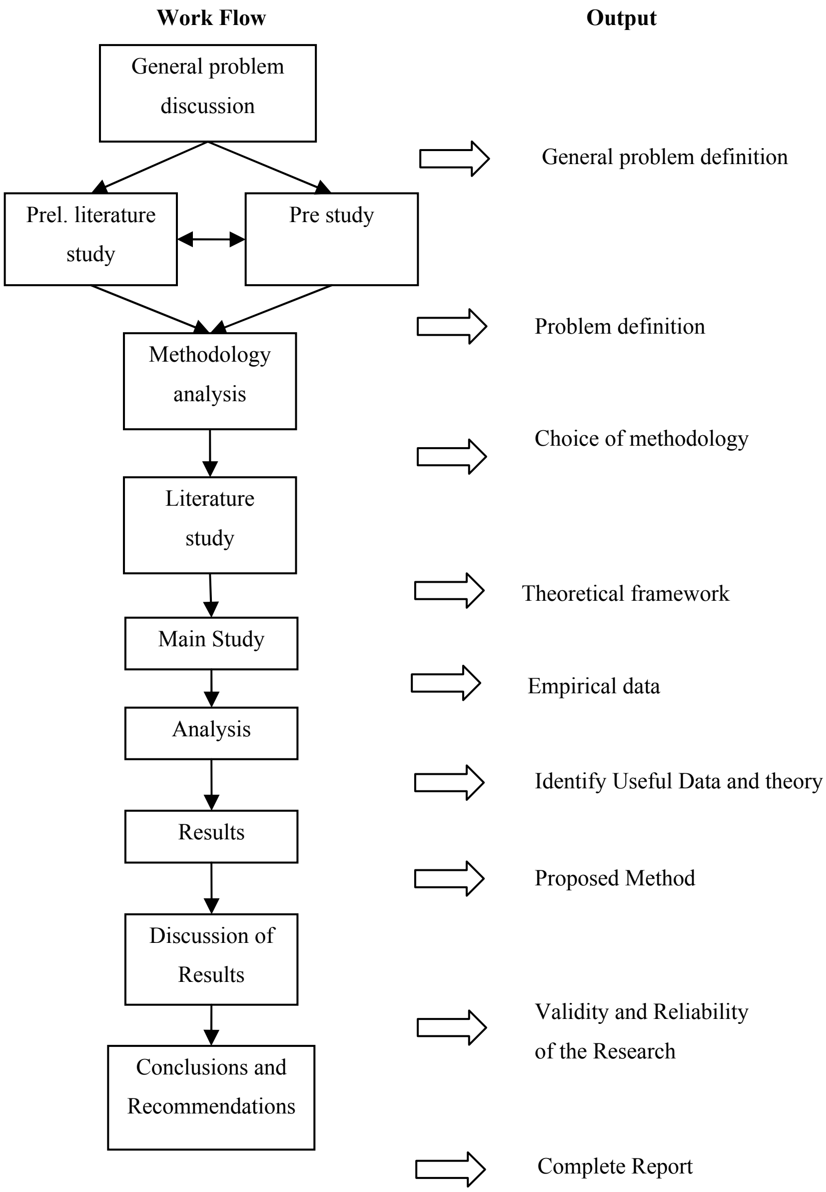

Figure 5 Work Flow and Output of the Research

2.5. Empirical data collection for the main study

Empirical data for the main study derives from both primary and secondary data. Internal company documentation and academic research literature and papers have mainly been used as secondary data. Primary data will be collected by conducting explorative and deep interviews with key persons from the corporate functions identified to be a part of the product development process. A preliminary round of interviews was conducted for explorative purpose. A low level of standardization and structure that is significant for exploratory interviews characterized these interviews. Exploratory interview are commonly used in pre-studies in order for researcher to exploit and discover the area of study (Andersen, 1990).

After the preliminary round of interviews, planning and structuring of the forthcoming main interviews started. Kvale (1997) emphasizes the importance of planning and preparing for interviews in a study in order to ensure the quality of the interviews. Kvale (1997) also claims that the quality of the original interviews is crucial for the quality of the following analysis, verification and creation of the report.

In order to create the best conditions for an open interview with a lot of spontaneous answers from the interviewees, which Kvale (1997) suggests, one person asked all the questions while the other ones took notes. In addition, the persons taking notes asked supplementary questions if and when answers were unclear or needed more explanation.

The creation of the interview questions were built on the basis of Kvale's (1997) quality criteria for an interview, which says that the quality of the interview, among other things, depends on the extent to which the interviewees give spontaneous, comprehensive and relevant answers. Kvale (1997) also states that the shorter the question and the longer the answer, the better. These aspects were taken into consideration during the preparation and realization of the interviews. The questions prepared for all the interviews were standardized, which meant that all interviewees received almost identical questions in the same order. The questions were thereby formulated as a check-list which facilitated the performance of the interviews and thus, important aspects were not forgotten. This enables the researchers to view a problem from different aspect and with different focus (Andersen, 1990).

Targeted persons for the interviews were personnel from different areas in the organization, who worked with cost estimates, commonality issues and financial considerations. These people were thought to be most relevant to interview in order to explore the cost of change.

All targeted persons were interviewed between 1 and 2 hours and the questions for the interviews can be found in Appendix I.

2.6. Validity and reliability

According to Patel and Davidson (2003) and Räisänen and Björk (1997) the validity and the reliability of the study is crucial. The validity tells if the phenomenon that is intended to be studied is actually studied and the reliability of the study relates to whether the measurement process of the study is free from random errors.

In order to improve a study's reliability and validity a number of methods have been applied. These methods are based upon Yin (2003) conclusions that multiple sources of information and that discussion with key informants increase the validity of a study. Validity has been improved by having key informants at VCC to review drafts of the thesis repeatedly and discussed the ongoing work. Whenever possible, multiple sources of information have been used. This improves the validity of the thesis further. Reliability has been improved by using case study protocol.

The validity of the data collection has also been improved by using Kvale (1997) methods. Since more than one person has been interviewed, answers could be compared. This supports the validity of the study. Furthermore, both authors attended all the interviews, which lead to careful and broad analyses of the interviews. This, in addition to the standardized way of carrying out the interviews, supports the reliability of the study.

Immediately after the interviews were carried out, the answers were analysed and compared with other interviews and the authors´ expectations, in order to draw conclusions. Patel and Davidson (2003) claim that it is important to know that a person's previous experiences and knowledge influence the interpretation of the information given by semi-structured interviews. It is therefore important that the analyses of the answers from the interviews are accurate and carried out with this taken into account. This was done through discussions and thorough explanations of everybody's thoughts and interpretations. Another important aspect to consider is carefulness about generalisation of the conclusions drawn from the study, since these are only built upon one case.

3. Theoretical Background

In order to understand the product development process and to provide this process with efficient tools, considerations of many areas of research needs to be done. In the preliminary literature study some research areas were identified to be important for the main study. They were value based decision making, communication and collaboration within companies, the impact and efficiency of decision support tools, customer satisfaction theory, cost consideration and implications of product platforms on the product development process. See Appendix II for the databases and search words used in this study.

3.1. Value based decision making

Bragaw et al (1997) investigate the benefits for managers to use value-based decision-making. Their research is derived from the decreased quality and innovativeness when firms invest heavily in cost reductions. Further the authors discuss the trade off between short and long term financial performance and argue that cost reductions tend to increase financial performance in the short run but can decrease financial performance in the long run. The authors moreover argue that value based decision-making help manager to achieve balance between short and long term performance goals.

3.2. Communication and collaboration

Allen (1971) showed that cooperation and communication among engineers within R&D-departments leads to successful projects. Griffin and Hauser (1993) and (1996) analyzed this further and showed that project success is positively correlated to the level of cooperation and communication among marketing, manufacturing and R&D leads to greater new-product success and more profitable product. Griffin and Hauser (1996) further listed a number of methods, including management support and formal collaboration processes, to increase cooperation and communication between R&D and marketing.

3.3. Decision support tools

Robertson and Ulrich (1998) state that the need for pushing for facts, not someone's "gut feel" of the answer, has been shown critical for using decision support tools. They further argue that management should ask for and get the best possible data. This is not to suggest that analyses should be detailed, bulletproof research papers. Rather analyses should be based on the best facts available, and not on personal hunches. Therefore, according to Robertson and Ulrich (1998), it is important to not insist on total agreement and perfect resolution of all issues, but rather focus to achieve a solution that everyone believes are good enough on all dimensions, and very good relative to the few critical competitive dimensions.

Steele (1988) investigates R&D project selection objectives and concludes that the increasing scale and complexity force managers to use formal decision procedures, of which scoring techniques are likely to be most widely used. Steele (1988) further argue that the growing scale and complexity of demands on R&D management are probably leading to higher priority on understanding context and orchestrating the involvement of more heterogeneous participants. Moreover, Steele (1988) states that formal decision support tools provide a language for all members of the organization to use in evaluating programs and the tools provide systematic rather than objective evaluation process.

Zhao et al (1993) stated that in order to be effective the product development process needs effective decision support tools. Maylor (2000) identified a need of improved assessment of tools and techniques in order to reduce the gap between the rhetoric and the reality of process improvement

3.3.1. Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is a well known and commonly used methodology for describing the inter-relationships between customer requirements and technical attributes (Akao, 1990). Griffin and Hauser (1993) showed that QFD was an efficient tool to improve cooperation and communication within firms. Quality Function Deployment is a concept and mechanism for translating the voice of the customer into product features. QFD has been used as a customer-oriented approach to facilitating product design by analyzing and projecting customer requirements into product attributes. The inter-relationships and correlations between customer requirements and technical attributes have to be taken into consideration in order to achieve high customer satisfaction and are therefore critical to the success of new product development (Akao, 1990 and Wasserman, 1993).

The relationships between customer requirements and technical attributes, and the correlation of technical attributes are often described in a House of Quality shown in Figure 6 (Akao, 1990). The correlation between customer requirements and technical attributes are often exemplified by a strong or weak connection and makes it possible to calculate the technical importance of each attribute.[1]

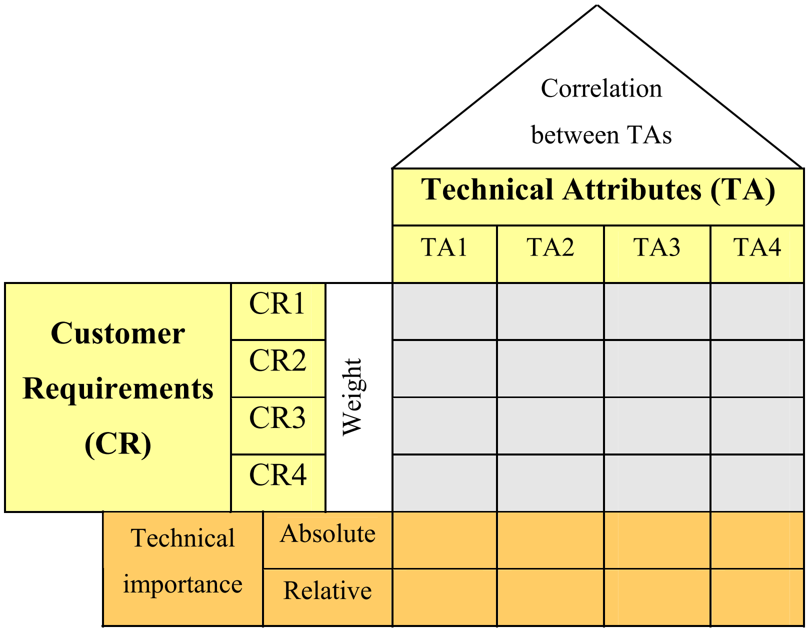

Figure 6 The House of Quality (Bergman and Klefsjö, 2001)

Traditionally QFD is used to maximize customer satisfaction by identifying target levels of technical attributes that achieve this goal. This methodology is technically one-sided and many authors have therefore identified the need for cost considerations when studying the inter-relationships between customer requirements and technical attributes. Bode and Fung (1998) states: *"...a manufacturing company is usually an economic enterprise which is under constant pressure to trade-off between quality and cost"* and *"...product design is not simply a maximizing effort but an optimizing process as well"*. Therefore, by introducing cost limitations into the QFD the product development process can be focused on optimization and not just customer requirement fulfilment maximization. Bode and Fung (1998) presented a model for treatment of the trade off between cost and customer requirement fulfilment by a linear program and concluded that top ranking customer requirements should be fulfilled first and thereafter complete to fulfil the requirements after their individual rankings.

[1] For an overview of Quality Function Deployment and how to perform a house of quality see Andersson, R (1991) QFD – *Ett system för effektivare produktframtagning*, Studentlitteratur, Lund

3.3.2. Value index

Tanaka (1985) introduced a QFD similar matrix method for product development management used for value optimizing products. The method is used to analyze how individual components together form product functions. These analyzes can be used to assign and visualize an importance value to each component. A value index for each component can be constructed by comparing the relative importance of each component to its relative cost. The method assumes that the trade off between customer importance and cost are proportionally and that the relative importance divided by the relative cost of the component should equal 1, see Equation 1. That is, cost should be allocated exactly in accordance with the degrees of importance of a product's functional areas. This assumption is based on the foundations of the Value Engineering[2], which is a process for increased profitability and cost reductions. The value indexes are plotted in a value index chart exemplified in Figure *7*.

$$\text{Value index} = \frac{\text{Relative Importance}}{\text{Relative Cost}} \tag{1}$$

[2] For an overview of Value Engineering see Cooper, R., Slagmulder R. (1997) Target Costing and Value Engineering, Productivity Press, Portland

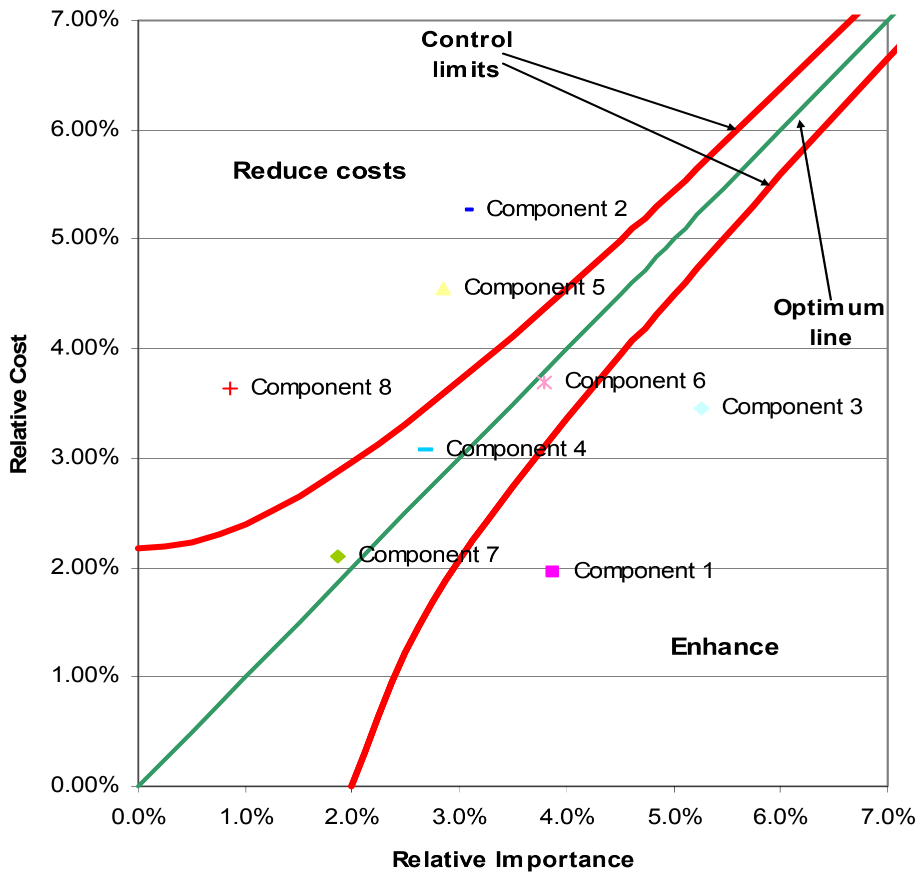

Figure 7 Value index chart (Tanaka, 1985)

Tanaka (1985) states that the optimum line requirements are too strict and introduce control limits to allow for deviations from the optimum line. The area within the upper and lower control limits are defined as the optimal value zone. The control limits are calculated as in Equation 2.

$$CL = \sqrt{x^2 \pm q^2} \tag{2}$$

Management sets the q values and Tanaka (1985) states that q < 20 % of the maximum relative value has empirically been shown to be suitable. The area of the graph above the optimal value zone indicates components that are candidate for cost reductions. Components that lie below the zone are candidates for enhancement, i.e. increase the functionality of the system.

3.3.3. Conjoint analysis

Conjoint analysis is a commonly used technique by marketing researchers for measuring and analyzing consumer preferences (Reutterer and Kotzab, 2000). Conjoint analysis decomposes overall measures of preference for hypothetical objects into the utility associated with different features or attribute levels making up that object.[3] Moreover, conjoint analysis has been shown to better capture customers' current preferences for product features while QFD captured what product developers thought would best satisfy customer needs (Pullman et al, 2001).

3.4. Customer satisfaction

Griffin and Hauser (1993) presents a thoroughly study on how to perform customer satisfaction by carefully examine customer requirements. The authors argue that the QFD customer requirement should be derived from different customer surveys and interview in order to investigate and analyze customer requirements and how to fulfil these.

Some researchers have expressed criticism to this focus on satisfying stipulated customer requirements alone. Christensen and Bower (1996) write about how customer power contributed to the failure of leading firms during a period of industry discontinuity. The authors conclude that developing a customer orientation appears not wise under conditions characterized by industry discontinuity. This conclusion is contradicted by long-standing theory and recent research in marketing. Slater and Narver (1998) distinguish between two forms of customer orientation. The first, a customer-led philosophy, is primarily concerned with satisfying customers' expressed needs, and is typically short term in focus and reactive. The second, a market-oriented philosophy, goes beyond satisfying expressed needs to understanding and satisfying customers' latent needs and is therefore long-term and proactive. Slater and Narver (1998) conclude that firms adopting the market-oriented philosophy are more successful in the long run. It could be argued that Slater and Narver's (1998) discussion is an addition to the Kano model, introduced by Kano et al. (1984). The model distinguishes between three types of product requirements: the must-be requirements are the basic criteria of a product, the one-dimensional requirements are proportional to the level of customer satisfaction, and the attractive requirements have a more than proportional satisfaction.

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[3] For an overview of Conjoint Analysis see Bergman, B., Klefsjö, B. (2001) *Kvalitet, från behov till användning*, Studentlitteratur, Lund

3.5. Cost considerations in product development

Milkie (1997) discusses the foundations of value engineering, i.e. value equals function divided by cost and suggests that cost considerations should be treated different depending on industries studied. The author describes the trends in the automotive industry to use variable cost as a proxy for product cost and suggests that this method isn't sufficient. A theoretical cost model should include all life cycle costs, including the cost of ownership. This would include for example, the costs of scheduled maintenance for the vehicle, the expected costs of component repairs out of warranty, depreciation over time etc. The author however realizes difficulties to estimate these cost in advance because of fluctuations in these factors. Milkie (1997) suggest a proxy for the total life cycle cost/vehicle illustrated in Equation 3.

$$\frac{\text{Total life cycle cost}}{\text{vehicle}} = \frac{\text{Variable cost}}{\text{vehicle}} + \frac{\text{Investment}}{\text{vehicle}} + \frac{\text{Warranty}}{\text{vehicle}} + \frac{\text{Maintenace}}{\text{vehicle}} \qquad (3)$$

Where the investment element of this equation can be broken down in Equation 4.

$$\frac{\text{Investment}}{\text{vehicle}} = \frac{\text{Tooling}}{\text{vehicle}} + \frac{\text{Facilities}}{\text{vehicle}} + \frac{\text{Engineering}}{\text{vehicle}} \qquad (4)$$

Ansari and Bell (1997) argue that thoroughly cost analysis and cost planning needs to be performed in the product development process in order to strike the right balance between costs and customer value. Target costing has been identified as a useful method for cost analysis[4]. The authors argue that cost analysis and cost planning should allow prices to determine costs instead of the opposite where prices are set as a surplus percentage of the costs. Therefore, the target cost perspective makes cost estimates an input of the design requirements.

[4] The routines and procedures at Volvo Car Corporation are similar to the principles of target costing and the concept has extensively been examined at Volvo Car Corporation (see chapter 2.3.3). This justifies an exclusive outline of the basic of target costing in the theoretical background.

3.6. *Product development with product platforms*

Companies increasingly view platform strategies as a way to offer high variety in the marketplace while retaining low variety in their operations. Product platform decisions are linked to issues of cost, product quality and performance, and organizational structure. Therefore, product development with product platforms requires understanding about the issues of component sharing and cost implications of platform strategies.

3.6.1. Component sharing implications on product development

Iansiti (1994) argue that new products is the fruit of the fusion of new and existing knowledge and conclude that project success, measured in cost and time goals achievement, are dependent on how firms work with the integration of new technology. Meyer and Mugge (2001) discuss this further and describe the benefits for companies to implement platform strategies and conclude that an important issue when using product platform is the choice of which things to platform and which to differentiate. Sudjianto and Otto (2001) investigated cross-brand product platforms and suggest that for any platform, brand specific elements must be maintained unique and elements not identified as a brand carrier can be made common to a platform. Robertson and Ulrich (1998) investigate criterions for effective use of product platform and argue that there is a trade off between commonality and variety, and this is not a zero sum game. They further argue that customer care whether a firm offers a product that closely meets their needs; they do not care directly about the level of part commonality among a collection of products. The authors state that the differentiating attributes (DAs) should be analyzed with respect to their costs with a QFD similar methodology analyzing interdependencies between attribute and major physical elements of a product. Robertson and Ulrich (1998) present this theory in a QFD similar matrix illustrated in Figure 8.

Increasing value of variety to customer ↑		← Increasing cost of variety			
		System 1	System 2	System 3	System 4
	Differentiating Attribute 1	●	●		●
	Differentiating Attribute 2	●	○		○
	Differentiating Attribute 3	○		○	●
	Differentiating Attribute 4	●	○		●

Critical few DAs and systems

Figure 8 The relationship between differentiating attributes and major physical elements (● Strong interdependency, ○ Weak interdependency) (Robertson and Ulrich, 1998)

A cell of the matrix in Figure 8 is filled when a DA and the system associated with that cell are interrelated, i.e. when variation in the DA is likely to require variation in the major physical elements. In the upper left corner are the critical few on which platform planning are focused. Systems that are not related to important DAs should be rigorously standardised and incorporated into the platform. Variation in these systems does not offer value in the marketplace. Valuable DAs that are not related to costly systems can be varied arbitrary without incurring high cost, and so should be varied in accordance with market demands. Robertson and Ulrich (1998) further state that because the exact relationships between major physical elements and DAs depend on the final product architecture, the matrix should be viewed as approximate and representative of the team's best estimates during the product development process.

Sudjianto and Otto (2001) developed a matrix for cross-brand platform strategies shown in Figure 9, similar to Robertson and Ulrich's (1998) methodology.

		Importance to overall profit through brand differentiation	
		Low	*High*
Difficulty/ Cost of variety	*High*	Platform it	Analyze to decide
	Low	Does not matter	Offer brand-specific

Figure 9 Modularity matrix (Sudjianto and Otto, 2001)

Sudjianto and Otto (2001) argues that a dominant theme must be ensured on each product's specifications and aesthetics. Elements critical to brand identity must be made common across all products in a brand. The authors further argue that the set of elements not identified as a brand carrier can be made common to a platform.

Other categorisation techniques have been suggested as well. Fisher et al (1999) suggest a categorization of components into those with a direct impact on product quality and those with a limited impact on product quality. Tanaka (1985) suggests a categorisation of product attributes into functional and aesthetic components. This categorisation leads to categorization of how components influence and affect the product's attributes.

3.6.2. Product platforms influence on cost considerations

Gabszewicz (1983) studies component sharing across products and states that the opening of new product lines generally is accompanied with increasing overhead costs and that these costs may lead to restriction in the variety of goods that it would otherwise be desirable to produce.

Fisher et al (1999) argue that the cost related issues in platform decisions may be usefully thought of as the investment requirements for new products; the variable costs of production; and the system costs of production, distribution, and after-sale support. Fisher et al (1999) moreover state that investment in new products includes the costs of product development and the fixed costs of production. Each new and unique component generally also requires an investment in tooling or other fixed costs of production. In addition to investment costs and variable costs of production, firms incur system costs of production, distribution, and after-sale support. Examples of activities associated with such costs are quality assurance, procurement, and spare-parts inventory. These costs are driven in large measure by the number of unique parts present in the production and distribution system (Fisher et al, 1999).

3.6.3. Deviations from value optimised decisions

Robertson and Ulrich (1998) state that in an ideal world one would want to explicitly optimise the platform to achieve maximum profits. However, they found that this is difficult for three main reasons. First, data are scarce especially related to the value of a particular choice of differentiating attributes. Second, decomposing the value of a product into the value of a particular differentiating attribute is difficult. Third, there are no optimisations techniques for creative problem solving that often are needed in order to make the part conform the platform. Fisher et al (1999) add one problem with platform optimisation by stating that limitations of cost data leads to decisions deviated from value-optimised decisions. Because of these problems, in order to avoid paralysis by analysis the key to making the product development process a success is to get a solution based on platform requirements that is sufficiently close to optimum.

4. Building the theoretical framework of the method

The preliminary round of interviews and the literature study formed the foundation of the value balancing method. Statements in this chapter are therefore founded upon the findings in the literature study and the preliminary round of interviews. In order to capture all the different aspects that have been identified to be crucial in the product development process methods and techniques from a number of researches need to be incorporated into the method.

Akao's (1990) House of Quality captures the transformation of product attributes weighted by customer requirements into technical attributes which is necessary to translate customer input into technical data. By building the method on a well known theoretical basis like QFD the method is likely to provide a common language for the cross functional members of the product development process, according to Steele (1988). Moreover, Bode and Fungs (1990) cost addition to the traditional House of Quality creates the necessary value optimization (discussed by Bragaw et al (1997)) foundation.

The customer ranking of the attributes and costs of the systems should preferably be noted in relative numbers in order to improve usability and comparison, which is crucial according to Robertson and Ulrich (1998). With the customer ranking of the attributes and costs of the systems in relative numbers it is possible to calculate a value index and plot each system in a value index chart, as described by Tanaka (1985). If a system is not within the control limits, like system 1 and 2 in Figure 10, the product is not in balance and the systems should be moved within the limits. When a system is changed, either in order to reduce cost or enhance the system, a cost of change arises. Figure 10 illustrates a principle outline of the suggested method.

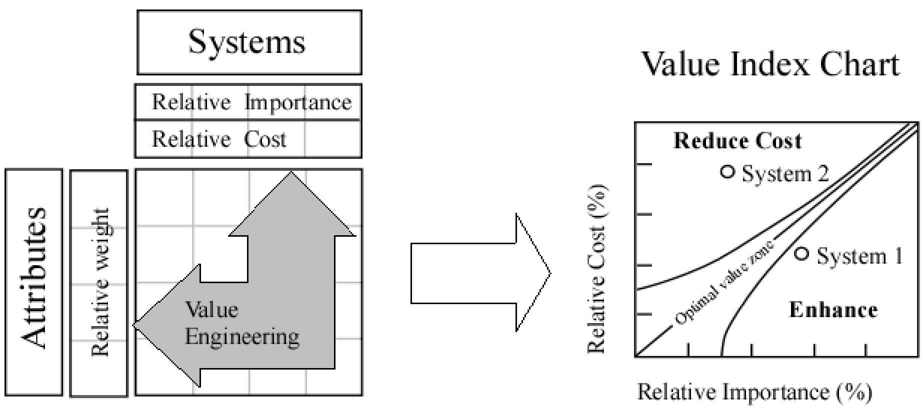

Figure 10 The Preliminary Method

The Robertson and Ulrich (1998) model for the relationship between differentiating attributes and major systems and Sudjianto and Ottos (2001) matrix for cross-brand platform strategies, described in chapter 3.6.1, would also be possible to incorporate into the method to support the platform decisions and to capture the important cost of change issues discussed by Bergman and Klefsjö (2001) and Shehab and Abdalla (2001), referred to in the introduction of this thesis.

The preliminary round of interviews revealed that it most likely would be possible to use the attribute areas, system categorisation and product cost data currently used at VCC. The areas that have to be investigated further in the main study are ranking of the attributes, product costs, allocation of product attributes on technical systems and cost of change for a system.

The remaining parts of the thesis will investigate and analyze how these models can be modified and adapted to support the fulfilment of the thesis's purpose, i.e. to develop a method that supports value balancing of customer requirements and costs in the concept phase of the product development process at VCC.

5. Presentation and Discussion of the Main Study

In this chapter findings from the main study are presented and discussed. Some findings and materials from the study can not be presented here because it is confidential.

5.1. Presentation of the results from the explorative study

The following sections describe the product development process and two cost calculation systems at VCC and are based on explorative interviews and VCC internal documents. The interviewed people are listed in Appendix III.

5.1.1. The product development process at VCC

The product development process at VCC is a large and complex process that requires several individuals and departments to work together. The process at VCC is controlled by a gate system where each gate has several conditions that must be met in order to proceed to the next level. There are 10 different gates in the Prestudy and Industrialization phase and there are three gates that are not officially included in the gate system. These three gates occur in the Concept phase and are characterized by a negative gate number who start with G-3 and ends with G-1, see Figure 11. The Concept Engineering Unit (where this study is conducted) works in the Concept phase with managing the different development units. The target with the Concept stage is to give a total business offer on the car concept, including the industrial structure. This means to define the product and the manufacturing processes regarding commonality, design, attribute profile, main dimensions, architecture, and system solutions. The Prestudy and Industrialisation stages shall also be planned and the offer for the Prestudy stage shall be decided and committed. The offer for Industrialisation, including variable product cost, shall be presented to be confirmed at gate G1. The target with the Prestudy stage is to develop the product and manufacturing process, including the complete industrial system, to be able to confirm the business case and take an industrialisation decision at gate G1. The target with the Industrialisation stage is to finish all detail drawings, make final verification and quality assurance for the product and the manufacturing process.

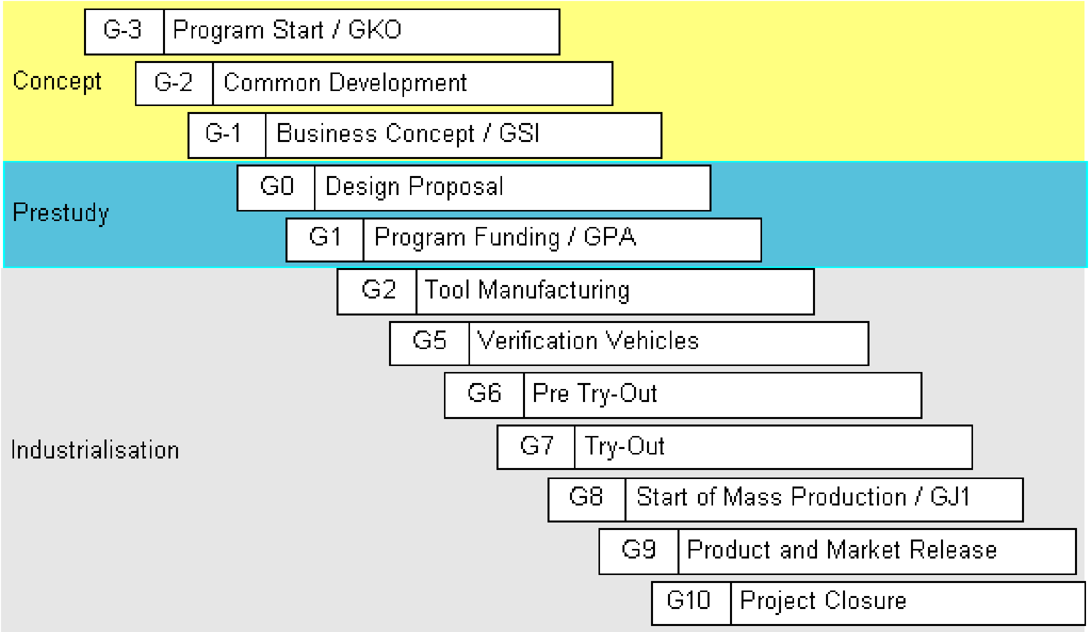

Figure 11 The Gate System at VCC

The product development process starts with a letter of intent from the product-planning department (PPL). This letter of intent shows the position of the vehicle on the market, market segments, competitors, etc. Other information is what kind of performance, attributes, features and price the new vehicle should have. This information is evaluated and results in a description of characteristics (EB). The EB is description of the functional performance, features offered and technology, that should be improved in the new car relative to an old one or a reference vehicle. The technology is described only if it is important to the customer. The inputs to the EB are for example market research, suppliers, literature, competition, government legislation and exhibitions.

The EB is divided in seven main attribute areas and 22 attributes at a lower level, with one responsible person for each, where each area is explained in "soft" terms how the vehicle should be perceived from a customer perspective, e.g. "*The new vehicle should have the best Climate Comfort in its class*". The different areas of the EB can be seen in Figure 12 and a definition of the attributes can be found in Appendix IV. Each attribute area is described in terms of Scope of Attribute Area, Background, Present Situation, Business Environment and required attributes. The terms emerge from discussions between the responsible person and other sources, and therefore there is no clear correlation between what customer desire and what is expected from the car. The objective with the EB is summarized in a *Product Attribute Profile* (PAP), which shows all attributes on a ten-based scale. If the vehicle is within the top ten-percentage range, it belongs to the best within that area.

Main Attributes (EB)	Attributes (EB)	Attributes (FKB)
SAFETY	PASSIVE SAFETY	CRASHWORTHINESS
		FIRE SAFETY
	ACTIVE SAFETY	BRAKE PERFORMANCE
		ACTIVE SAFETY
	SECURITY	SECURITY
ENVIRONMENT	FUEL CONSUMPTION	FUEL ECONOMY
		AERODYNAMICS
		WEIGHT
	EMISSIONS	EMISSIONS
	CLEAN COMPARTMENT	ENVIRONMENT
	MATERIALS & RECYCLING	ENVIRONMENT
QUALITY	RELIABILITY/DEPENDABILITY	RELIABILITY
		ENDURANCE
		CORROSION
		THERMO
		EL PERFOMANCE&EMC
		WATER TIGHTNESS
		CONTAMINATION
		AGEING POLYMER MAT.
	SOLIDITY	SOLIDITY
	DESIGN QUALITY	DESIGN QUALITY
		PAINT&SURFACE FINISH
DESIGN	DESIGN	DESIGN
DRIVING EXPERIENCE	HANDLING	HANDLING
	RIDE COMFORT	RIDE COMFORT
	NOISE COMFORT	NOISE/VIBRATIONS
	PERFORMANCE / TRACTION	PERFORMANCE
	DRIVEABILITY	DRIVEABILITY
		CLEARANCE
CONVENIENCE	ROOMINESS	ERGONOMICS
	DAILY LIFE USAGE	ERGONOMICS
	HUMAN FACTORS	ERGONOMICS
	CLIMATE COMFORT	CLIMATE COMFORT
	INFOTAINMENT	INFOTAINMENT
COST	RESIDUAL VALUE	RESIDUAL VALUE
	RUNNING COST	SERVICE

Figure 12 Attributes at EB and FKB level

Another group of people work close together with the people from EB to produce a *functional requirement description* (FKB). The FKB describes in a quantitative analysis how to accomplish what is described in the EB, e.g. "*Passenger compartment should be maintained at 20˚C temperature when the outside temperature is 50˚C*". The description is first made on complete vehicle level and then broken down to 37 *product structure systems* (PSS), see Appendix V for a listing of them.

5.1.2. Product Cost Calculations at VCC (ProCost)

ProCost is an IT-tool designed for controlling of Product Cost and Investments in the R&D projects of VCC. In order to provide design teams with necessary support to control and achieve cost targets, ProCost has been developed and implemented at VCC and is available through the company's intranet. ProCost contains calculations concerning:

- Unit cost (Material value)
- Logistics cost (Transport from supplier to VCC assembly site)
- Assembly cost (Cost of net operation time at VCC assembly site)
- Facilities & Tooling (Type bound equipment and other investment directly related to the development of a new product)

The application is divided into two parts. The first is registration and storing of cost targets and cost estimates. The second part provides seven different cost control reports, see Appendix VI for a summary of the available reports.

5.1.3. Product Cost Calculations at VCC (PreCost)

Another IT-tool, available trough a Lotus Notes-application, is PreCost where requests and cost estimates for different projects are documented. Request is a request from a customer to a supplier to perform a certain task and cost estimates are estimates of different costs for projects. PreCost contains calculations called FTLE and the letters stand for:

- Facilities (Investments in facilities, e.g. larger factory)
- Tooling (Investments in tooling equipment for manufacturing)
- Launch (Costs for preparation of launch)
- Engineering (R & D costs in man- and rig-hours)

The first three (F, T and L) are imported from ProCost and the soft costs, i.e. Engineering costs, are estimated separately in PreCost. From the application it is possible to view reports from different perspectives, e.g. FTLE-costs per PSS, per cost carrier, per projects etc, and also export them to EXCEL-format.

5.2. Platform usage at VCC

Ford Motor Company (FMC), and subsequently VCC, defines a platform as a set of sheet metal underbody subassemblies, front structure, front floor and rear structure. VCC strives to achieve a high degree of part commonality between products, not just with other FMC brands but also with other VCC products. Within Ford Motor Company the following definition of part commonality is used.

Common

- Reused (P) – Existing part shared by multiple vehicle lines and/or brands. Can also be carry forward from prior model.
- Modified (M) – New part derived from "donor" part, shared by multiple vehicle lines and/or brands. At least 70-80% tooling and /or engineering reuse.
- New (X) – All new part shared by multiple vehicle lines and /or brands.

Unique

- New (U) – Unique part not shared across vehicle line or across brands. A unique part adopted by a second program is categorized as reused (P).

Overall targets are set by combining the three types of common parts (P+M+X) and measure the fraction common part value per total vehicle value.

The first step in platform planning is to decide which underbody structure to use. When the underbody structure is set, the primary focus will be on choosing which major systems to use. Commonality plans pushes the development to use systems common to other FMC vehicles. Functional requirements may call for the system to be modified (category M). If the functional requirements cannot be met by this procedure a new system will be developed. This system will preferably be suitable for use on other vehicles and thereby fall into category X. If no other applications can be found for the system it will be categorized as a unique system (U), which is the least preferable from a commonality perspective.

5.3. Presentation of the interviews to find a proxy for cost of change at VCC

The cost of change has been identified as an important issue in product development planning. Since cost of change currently doesn't exist in VCC's routines and procedure a proxy for cost of change has to be identified. Therefore interviews are conducted to find a suitable proxy for cost of change. This chapter presents a summary of the interviews. The questions and a list of the respondents can be found in Appendix II and VII.

In the prestudy and study of previous research at VCC it was found that complexity might be a suitable proxy for cost of change. Questions about complexity were therefore asked to the interviewee in order to investigate this further.

The definition of cost of change that was given to the respondents was:
"Systems that are not within the given limits should be changed. In order to understand the efforts needed to change the position of a system in the value index chart, a cost of change classification of the systems will be implemented in the method. We define cost of change as the cost of implementing a new or changing an old technical system when constructing a new car. The cost of change for individual systems should not be considered in correlation with other systems".

All interviewee responded that the cost of change for a system depends on several aspects. The two most important are according to almost all interviewees investments for manufacturing (tooling costs) and product development cost. Another important aspect that many interviewees discussed was that the cost of change in some cases had to be treated different depending of if it was in-house developed and manufactured system or a system that is supplied from an external source. If it is an external source the supplier bears most of the development. The tooling cost is not included in the price from the supplier because VCC pays for the manufacturing tools and owns them, according to several interviewees.

From the interviews it is also clear that there is a commercial issue when changing a system. If the supplier is already contracted and a change is wanted to the system the supplier might charge a higher price, i.e. if the change occurs late in the product development phase it will probably result in a higher cost. The cost of change might also depend on whether the part is unique or common for several products because they have different manufacturing volumes, according to interviewees. The change of the system will probably affect the unit cost and hopefully lower it. In the case of a lowered (or a higher) unit cost a *net present value* (NPV) analysis[5] could be performed. In that analysis the future cash flows from savings (or additional costs) should be discounted to present time and compared to the initial investment. A positive NPV-value is a favourable change and should be executed. Another method easier to use is payback time where it is calculated how many years it takes until the amount of savings equal the initial investment. A rule of thumb at VCC is that a payback time less than 1.5 years for a change of system should be executed, according to one respondent.

[5] NPV=Net Present Value, which is the current value of an amount of future cash flows. It is a function of the amount of time into the future and the interest rate used. This method is covered in most finance textbooks (for example Brealey and Myers (1984), Principles of Corporate Finance, McGraw Hill) and will not be explained in detail here.

If a comparison should be made between systems for their cost of change, the two most important costs are tooling and product development to include in the comparison, according to a majority of the interviewees. Another criterion for comparison is the complexity of the systems. All respondents thought that it was possible to use complexity to rank the different systems in order of cost of change. The respondents gave diversified answers to the question of how to define complexity of a system, when considering cost of change. Complexity could be the number of parts and the size of the system. Another way to look at complexity is to consider if the system interacts with other systems. If it interacts with other systems a change in that system will require changes in the other systems. It is also possible to look at complexity as how many functions the system carries, i.e. if the system is responsible for many functions it is more complex. Other issues named by the interviewees were manufacturing processes, number of suppliers to the system and if the system is manufactured in-house or by an external supplier.

5.4. Presentation of the results from the interviews for attribute classification

PPL are preparing a study, called Attribute Balance Study, which will investigate how customers rank Volvo cars against other premium brands. The target group is new car buyers who have purchased their car during the years 2000 to 2003 and have bought a Volvo or a car from the competitive set. The interview starts with a screening and some sociodemographics, followed by a small conjoint analysis. In the conjoint analysis the interviewee are asked which attribute out of two that are most important for him or her. The interviewees are then asked to rate the attributes for their car on a ten-grade scale and also rate the brand attractiveness.

Results from the Attribute Balance Study are not yet ready to be published and therefore, in combination with confidentiality agreements, this thesis is unable to present or refer in detail to the ongoing study. However, after discussions with a member of the Attribute Balance Study it is the authors' strongest belief that the forthcoming outcome of the study will be suitable as customer ranking input to product attributes of the method. Since there is an ongoing study with focus on exactly the questions asked in this thesis regarding customer requirements less work efforts has been made on this topic.

6. Analysis

In the analysis chapter the input data for the forthcoming proposed method, from now on referred to as the Value Balancing Method, will explored and analysed in order to convert and adapt the proposed theoretical framework model into a useful method. The theoretical framework models are presented in Figure 9.

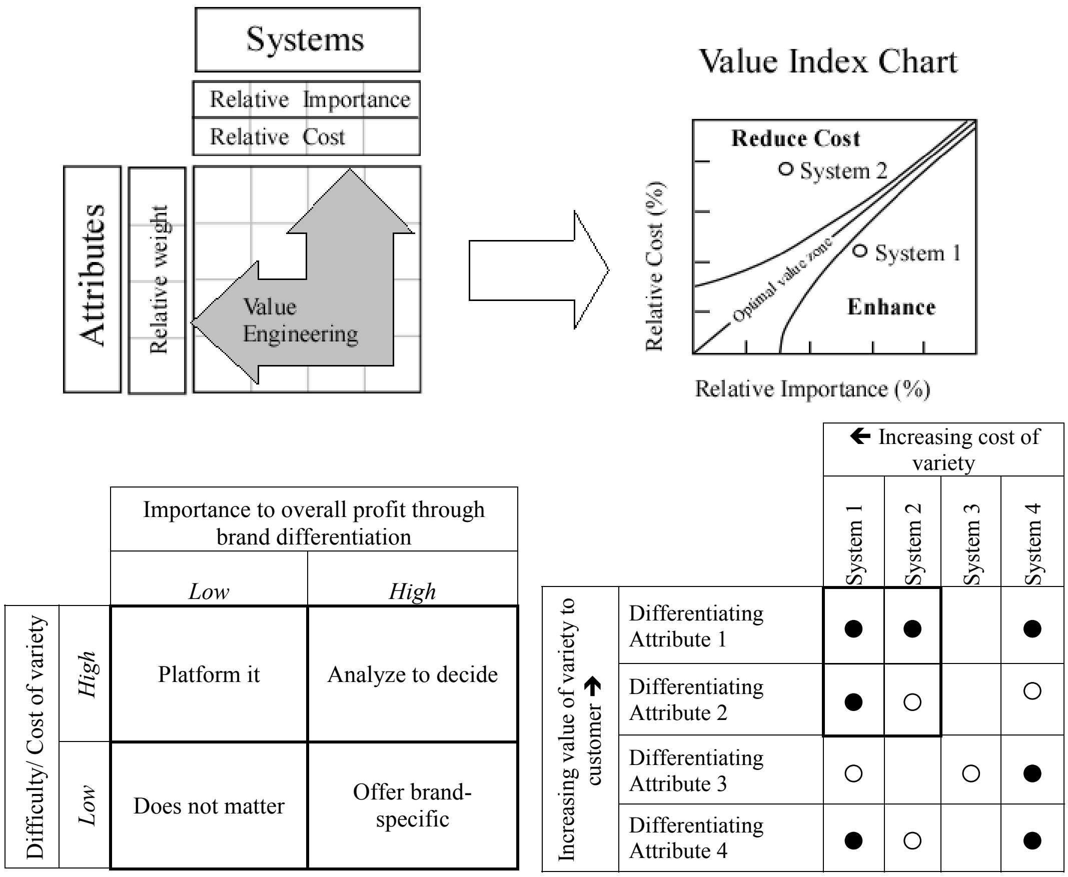

Figure 13 The theoretical framework models

6.1. Customer requirements

The traditional QFD-matrix, introduced by Akao (1984) uses customer requirements as input and transforms them into technical components by various allocation methods. Since Steel (1988) claims that using existing routines and structure of the company, communication and collaboration within the organization will be easier. In order to use existing routines and structure at VCC it would be possible to use available information as customer requirements and incorporate it into the Value Balancing Method.

6.1.1. Attributes

Söderqvist (2004) concludes that the allocation of the attributes to technical systems in the Value Balancing Method needs to be performed at a FKB attribute level, since attributes are assigned technical requirements at FKB level. However, there are 35 attributes at FKB-level at VCC. An efficient customer ranking would be difficult to perform when 35 different attributes need to be analysed and the attributes at FKB level are too technical for customer to rank them. Therefore, customer ranking needs to be performed at a higher attribute hierarchal level. VCC works with product attributes to describe product features and functions as customer experience them when using the product at EB-level. Therefore the attributes would preferably be ranked at an EB-level (see Figure 12).

The transformation of the customer ranking of attributes at EB level to FKB level could preferably be done with a regular analysis of strong-middle-weak connection between the attributes in a QFD method without attribute ranking, described by Akao (1984).

Since the product attributes at EB-level are derived from several actions: market research including customer analysis, long term strategic decisions of core values of the company, and competitor analysis, VCC would adopt a market focused strategy instead of a customer focused strategy when using these attributes as customer requirements, which Slater and Narver (1998) concluded to be the most efficient market strategy.

6.1.2. Ranking of attributes

The best customer requirements ranking data at EB-level would come from PPL's Attribute Balance Study, described in chapter 5.4. As noted earlier, results from the Attribute Balance Study are not yet ready to be published. However, the results from the Attribute Balance Study will preferably be used as ranking of the attributes at EB level. Since there is an ongoing study with focus on the same questions requested in this thesis concerning customer requirements less work efforts has been made on this topic. By using the forthcoming results from the Attribute Balance Study, the work effort needed to use the Value Balance Method would decrease. Moreover, by using data from the department responsible of this kind of issues the results from the method is likely to be improved and the method is expected to easier gain acceptance in the organization.

While waiting for the results of the Attribute Balance Study it would be possible for a cross functional group of VCC-people to make estimates of the ranking of attribute at EB-level by using conjoint analysis. The cross functional team would preferably consist of representatives from the departments involved in the product development process. This method to receive the customer importance data is easy to perform because it requires a low work effort. But they are not based solely on the voice of the customer and market conditions; rather the ranking would be a function of what VCC thinks are important for the customer.

In order to further improve the communicative and collaborative features of the Value Balancing Method the method would benefit from using relative data since this enables comparisons between different products and makes the method easier to overview. Therefore the attribute ranking probably has to be modified to view relative numbers.

The relative importance in the models in Figure 13 is the relative importance of the PSS. By using the relative importance of the PSS instead of “increasing value of variety” in the Robertson and Ulrich (1998) and the “importance to overall profit through brand differentiation” in the Sudijanto and Otto (2000) matrices would be notably changed. However, the matrix would still provide very useful information since it still would put the most important attributes in focus and since the work effort needed to implement the original matrices are significant an adaptation to available information is still preferred. If other data was introduced the work effort needed to use the method would increase and confusion might occur when communicating the results within the organization. The method would therefore be easier to work with and to communicate by using a common language throughout the method.

6.2. Technical systems

The break down of the product into technical systems needs to be logically and adapted to the current organization at VCC in order to gain acceptance and approval of VCC. The Value Balancing Method would therefore benefit from using VCC’s 37 PSS as technical systems.

6.2.1. System costs

The QFD-matrix in the preliminary model, described in chapter 3, needs cost data as input for the calculation of relative data. Milkie (1997) argues that the tendency in the automotive industry is to use variable cost for Value Engineering purposes because of its simplicity. His proposal is that a cost estimates should include all life cycle cost (see Equation 5).

$$\frac{\text{Total life cycle cost}}{\text{vehicle}} = \frac{\text{Variable cost}}{\text{vehicle}} + \frac{\text{Investment}}{\text{vehicle}} + \frac{\text{Warranty}}{\text{vehicle}} + \frac{\text{Maintenace}}{\text{vehicle}} \tag{5}$$

Where the investment element of this equation can be broken down in Equation 6.

$$\frac{\text{Investment}}{\text{vehicle}} = \frac{\text{Tooling}}{\text{vehicle}} + \frac{\text{Facilities}}{\text{vehicle}} + \frac{\text{Engineering}}{\text{vehicle}} \tag{6}$$

The existing accounting system at VCC incorporates the variable and investment costs in Milkie's (1997) model described in Chapter 3.5 but not the warranty and maintenance costs. The variable cost, investment cost and forecasted sale volumes are available for current car projects in PreCost at VCC and therefore it would be possible to use the Milkie (1997) model as PSS cost estimates in the Value Balancing Tool. The cost estimates are not likely to be significantly affected by leaving the cost of maintenance and warranty out of the equation since investment cost and variable cost per vehicle are significantly larger than warranty and maintenance cost per vehicle. It could also be argued that the two cost variable should be excluded because of the difficulties in measuring them on a technical sub system level of a product.

Milkie's (1997) further argues that the time value of money should be taken into consideration and therefore an NPV-calculation should be done for the costs over their lifetime. Ansari and Bell (1997) also argues that *life cycle costs* are important to consider. They even claim that *full product cost* should be used because profit planning and customer prices are at the total product level, i.e. at Product Planning Department (PPL) level at VCC. In their opinion, many companies place undue emphasis on the costs of manufacturing and purchased parts and this tend to place too heavy burden for cost reduction on engineering design while other support costs escape scrutiny. On the other hand they write that consistency with existing definitions is important for both communication and evaluation of performance against targets. This is important because if cost targets include definitions that are not part of a company's existing accounting system, then the cost is liable to create confusion and cause the model to become less credible.

By separating investment cost from calculation an analysis of the cost of change would be possible. Since such analysis has been shown to be important this cost estimate that doesn't include investment cost is preferable. According to theory and existing accounting system at VCC, the cost data for the technical systems should be the sum of unit, logistics, and assembly per system. This would provide the best trade-off between adaptation to current routines and procedures at VCC and academically proposed cost estimates.

6.2.2. Cost of Change

The cost of changing a system has been studied in this thesis because of its relevance when a system is located outside of the control limits in the Value Index Chart. As described in the introduction tot his thesis the importance of cost of change in product development has also been concluded as crucial by Bergman and Klefsjö (2001). The cost of change could probably be used as a proxy for "difficulty /cost of variety" in the Sudijanto and Otto (2001) model and "increase cost of variety" in the Robertson and Ulrich (1998) model. These changes to the models wouldn't change the outcome of the results from the models and therefore the change of cost is a justified proxy to use.

The main interviews showed that the cost of change for a system depends on several things. All of the respondents believed that complexity was in relation to what it would cost to change a system. The definition of complexity of a system was not clarified. Many approximations for complexity were given, e.g. number of parts, interactions with other systems and how many functions the system carries. Since no clear answer on how to define complexity was attained from the interviews and because of the complexity of defining "complexity", the approach to base cost of change on complexity was discarded.

A better way to measure the cost of change is probably through finding a efficient proxy for what it actually cost to perform a change to a system. In this matter almost all respondents gave the same answer that cost of change depends on investments in facilities, tooling and development (Engineering). The explorative study revealed that these costs are calculated and available for historic and current car projects through the FTLE-calculations in PreCost. The degree of modification should be taken into consideration since some of these costs depend on how large the change to the system is. A well-suited classification of the different degrees of change to a system would be to use the same nomenclature as in chapter 5.2 , i.e. Reused (P), Modified (M), New (X) and Unique (U), for a change to the systems. With this classification it might be possible to retrieve historical data, from PreCost, for every degree of change and thereby classify every system in order of their relative cost of change.

6.3. Summary of analysis

The customer ranking of the attributes should preferably be done at an EB attribute level and the allocation of the attributes to technical systems at a FKB attribute level. The transformation of the customer ranking of attributes at EB level to FKB level could preferably be done with a regular QFD method without attribute ranking. While waiting for the results of the Attribute Balance Study it would be possible ranking of attribute at EB-level in a conjoint analysis performed by a cross functional team.

The Value Balancing Method the method would benefit from using relative data since this enables comparisons between different products and makes the method easier to overview.

The Value Balancing Method would preferably use the VCC's 37 PSS as technical systems and the cost data for these should be the sum of unit, logistics, and assembly. The proxy for the cost of change should be the investments in facilities, tooling and development (Engineering) and retrieved from the FTLE-calculations in PreCost.

Relative importance of the PSS and the cost of change could be used in the Sudijanto and Otto (2001) and the Robertson and Ulrich (1998) model.

7. Proposed Method

In this chapter the results from the analysis will be incorporated into the proposed Value Balance Method in order to fully illustrate the method.

The preceding chapters have resulted in a proposed Value Balancing Method, which contains the following parts:

- Main QFD matrix
- Value Index chart
- Critical Attributes and Systems
- Modularity Matrix

The basic function of the main QFD matrix is to visualize the allocation from product attributes to technical systems and calculate value indexes for all of the systems. It uses ranking of customer attributes and system cost data as input. The allocation function structure provides the data for the connections between attributes and technical systems in the main QFD matrix. The attributes are sorted after increasing relative attribute ranking and the systems are sorted after increasing cost of change. This makes it possible to detect the connections of critical Attributes and Systems as described in chapter 3.6.1. From the data in the Main Matrix it is possible to generate a Value Index chart and a Modularity Matrix, which are used to evaluate the platform configuration. These parts are described in the following chapters.

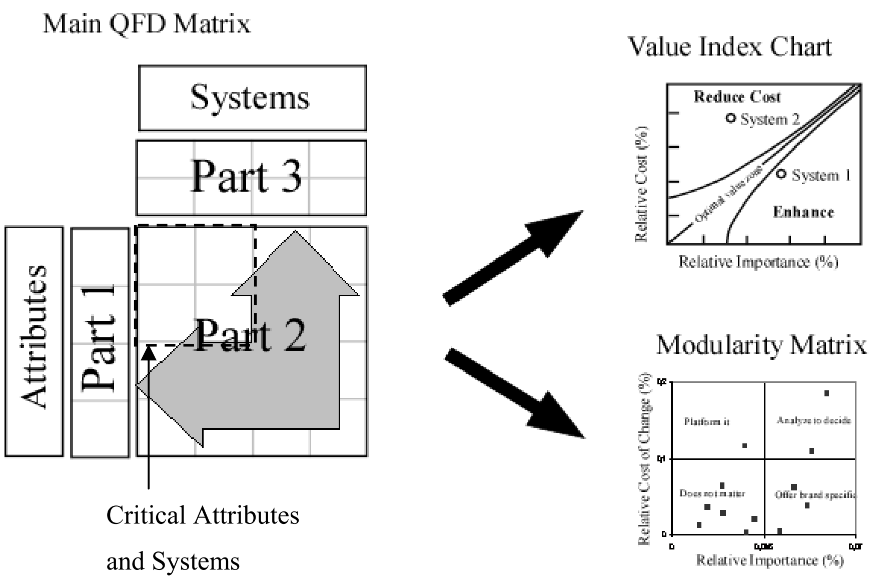

Figure 14 Overview of the Proposed Method

7.1. Main QFD matrix

The main QFD matrix will be described in the following three sections. The description will be divided in three parts and follows the schematic picture in Figure 14. A complete picture of the QFD matrix can be found in Appendix IX, but it has been modified to not reveal any confidential data and results.

7.1.1. Part 1- Customer Importance

Part 1 of the proposed method consists of customer importance ranking for different attribute areas. The attributes are presented at three different levels, the two first are at EB-level and the last is at FKB-level. The attributes at FKB-level are in decreasing order of relative ranking with the highest ranking at the top. How to get the relative ranking at FKB-level is described below.

The proposed way to get customer importance data to the QFD-matrix, is to transform the ranking at EB-level to relative ranking at FKB-level. The data at EB-level is assumed to be available, either from the forthcoming results of the Attribute Balance Study at PPL or meanwhile from a cross functional team at VCC performing a conjoint analysis. Some of the attributes in the EB have several FKB areas and the relative attribute ranking needs to be further distributed to these FKB areas. This is done with a regular QFD-matrix with strong (9), medium (3) and weak (1) connections between attributes and FKB areas. An example of this procedure with five attributes and their respective FKB areas are shown in Figure 15. In this example it can be seen that there is a strong connection between Passive Safety and Crash Safety and that the latter should have 90 percent (0.9) of the ranking that Passive Safety has while Fire Safety will get 10 percent.

FKB / Attribute	CRASH SAFETY	FIRE SAFETY	SECURITY	BRAKE PERFORMANCE	FUEL CONSUMPTION	ACTIVE SAFETY	EMISSION	SUM
PASSIVE SAFETY	9	1						10
ACTIVE SAFETY				9		9		18
SECURITY			9					9
FUEL CONSUMPTION					9			9
EMISSIONS							9	9

FKB / Attribute	CRASH SAFETY	FIRE SAFETY	SECURITY	BRAKE PERFORMANCE	FUEL CONSUMPTION	ACTIVE SAFETY	EMISSION	SUM
PASSIVE SAFETY	0,9	0,1						1
ACTIVE SAFETY				0,5		0,5		1
SECURITY			1,0					1
FUEL CONSUMPTION					1,0			1
EMISSIONS							1,0	1

Figure 15 From EB to FKB area with QFD-method

In Figure 16 the results for part 1 are summarised. The proposed method transforms the ranking at EB-level to relative ranking at FKB-level.

EB (Main)	EB (Attributes)		FKB	
SAFETY	**PASSIVE SAFETY**	**35,0%**	**CRASH SAFETY**	**31,5%**
			FIRE SAFETY	**3,5%**
	ACTIVE SAFETY	**20,0%**	**ACTIVE SAFETY**	**10,0%**
			BRAKE PERFORMANCE	**10,0%**
	SECURITY	**20,0%**	**SECURITY**	**20,0%**
ENVIRONMENT	**FUEL CONSUMPTION**	**12,5%**	**FUEL CONSUMPTION**	**12,5%**
	EMISSIONS	**12,5%**	**EMISSIONS**	**12,5%**

Figure 16 Summary of the results from the described method

7.1.2. Part 2 - Allocation Method

An allocation method that can be used for the Value Balancing Method was developed by Söderqvist (2004). A summary of the method is described in this section and a thorough description can be found in Appendix VIII.

The allocation from FKB to PSS is achieved by creating a function tree for each FKB area. The first level of the function tree defines the basic function of the FKB area and the subsequent functions describe how this overall function is achieved. The basic function could be "reduce passenger injury" for the crashworthiness FKB area. To each secondary function the PSS are linked by the following groups:

- Primary: The system is primarily designed to perform this function. E.g. the brake system has a primary contribution to the function provide braking torque
- Secondary: The system is partially designed to perform this function in cooperation with other system and has a smaller contribution compared to the primary system(s). E.g. the wheels and tire system has a secondary contribution to the function provide braking torque.
- Tertiary: The system is not originally designed to perform the function but has an indirect effect or contribution to the function. E.g. the engine system has a tertiary contribution to the function provide breaking torque by generating vacuum to the brake servo.

Each system can only have one type of connection to each function but can have connections to several functions.

The last step is to calculate the relative importance of each system to the basic functions. This is achieved by assigning weights of 9, 3 and 1 to primary, secondary and tertiary contributions. The weights from each function is added together and converted to relative values by dividing by the total number of weights assigned to the basic function.

7.1.3. Part 3 – Data for technical systems

In part 3 in the proposed method are the names and some calculated figures for the 37 systems (PSS) presented column wise, see Figure 17 for an example of three systems. The numbers in the matrix are for illustrative purpose only and do not reflect the situation at VCC.

	270 **Body structure**	300 **Transmission**	290 **Engine**
Value Index (imp/cost)	0,62	0,48	1,31
Relative Importance	6,2%	2,9%	5,2%
Relative Cost	10,0%	6,0%	4,0%
FTLE (Msek)	400	300	200
Product cost (SEK)	4000	2500	3000

Figure 17 Part 3 in the Main Matrix

The lowest row shows the Product costs for the different systems and is calculated with data from ProCost, see Equation 7.

$$\frac{\text{Product cost}}{\text{vehicle}} = \frac{\text{Unit cost}}{\text{vehicle}} + \frac{\text{Assembly cost}}{\text{vehicle}} + \frac{\text{Logistic cost}}{\text{vehicle}} \quad (7)$$

The row above Product Cost represents the cost of change and is Facilities, Tooling, Launch and Engineering (FTLE), from PreCost, added together. This cost describes how the systems differ in how expensive they are to change and the columns are listed in decreasing order of FTLE from left to right.

The next row is relative cost and is calculated as the product cost divided with the total product cost for all systems. The row, Relative Importance, is the sum of the column with relative customer importance ranking (in part 1), multiplied with the column with relative weights (in part 2) for each system. The last row is Value Index and is calculated as Relative Cost divided by Relative Importance.

7.2. Value index chart

Relative importance and Relative cost for each system can be extracted from part 3 in the main matrix and plotted in a *Value index chart*, see Figure 18 below.

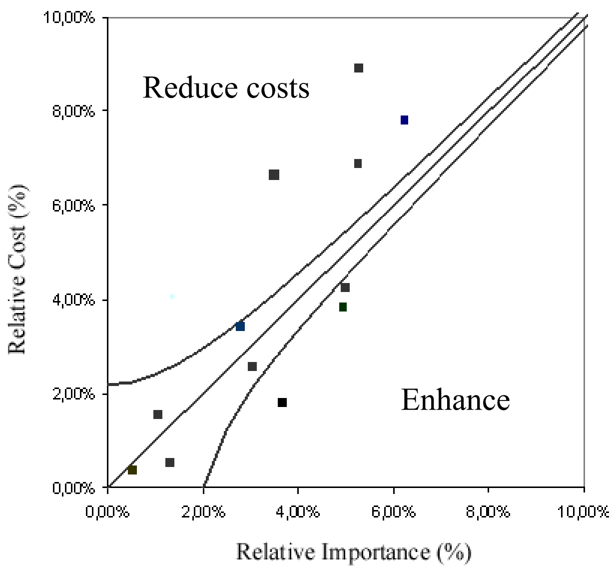

Figure 18 Value Index Chart

As described in chapter 3.3.2 the systems should be located within the optimal zone to achieve the overall targets on customer value. In this study the tolerance factor *q* is set to 15% of the maximum relative value. Tanaka (1985) argues that 15 % is an efficient value of q- However, this limit is difficult to estimate without testing the Value Balance Method and therefore the value of q is likely to be changed after implantation or testing. Systems above the optimal zone should be subject of cost reduction efforts or replaced with a system with lower cost since their functional contribution to customer value is too low compared to the cost of the system. Systems below the optimal zone have a functional contribution to customer value that exceeds the cost of the system. These systems should therefore be enhanced to further contribute to customer value. A reflection on the Value Index Chart is that it would probably be possible to increase the relative importance to customer by different actions, for example marketing efforts. Moreover, the chart could also be used to visualize how changes in systems affect the overall balance of the products. It would therefore be possible to use the chart to minimize balance effort, i.e. changes in systems, either cost reduction or functionality improvement.

7.3. Critical Attributes and Systems

The attributes in part 1 of the main matrix is listed in decreasing order of customer importance, from the top and down, and the systems in part 3 are listed in decreasing order of cost of change from left to right. Since the attributes and systems are listed in this way it is possible to apply a modified version of Robertson and Ulrich (1998) model, described in chapter 3.6.1, to the main matrix in the proposed method. The upper left quadrant in part 2 will be the area where the critical few Attributes and Systems are located, see Figure 19 and Appendix IX. The relative weights (in part 2) for the connections, between attributes and systems, have a red colour if it is a strong connection and yellow if it is a weak connection. With this colour coding it is possible to identify the critical Attributes and Systems with strong connections where focused platform planning is required.

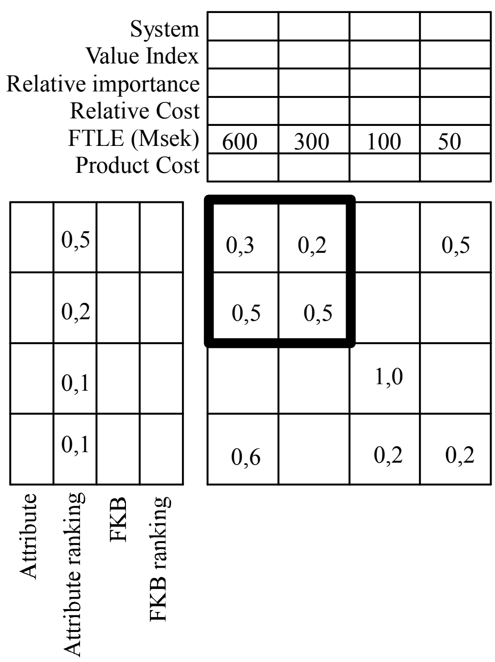

Figure 19 Example of the Critical Few-Quadrant

7.4. Modularity Matrix

From part 3 in the main matrix it is possible to extract values for relative importance and relative cost of change (defined as relative FTLE) for each system and plot them as in Figure 20.

As described in chapter 5.2, one can evaluate which systems to use standard solutions, like carry over and reuse systems, and which systems to offer as unique or modified systems. Systems with low importance to customer requirements and high relative cost of change should be assigned common standard solutions. These are the systems that are not identified as product specific carriers and are suitable to share with other models on the same platform.

Systems with a high relative importance to customer requirements and a low cost of change are efficient to modify and should therefore be offered in unique or modified solutions with a high degree adaptation to the specific customer group for the product. These are the systems that are important to the product identity and should not be shared with other models built on the same platform.

If the systems are placed in the upper right quadrant of the chart it is required to analyse in detail what the customer experience as important to product identity in order to make an appropriate choice of systems. Because of their strategic importance, these systems need extra attention by the product development team.

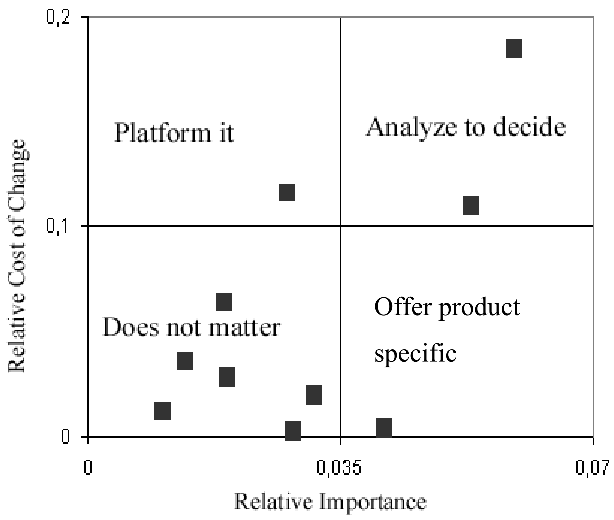

Figure 20 Modularity Matrix for Platform Strategies

8. Conclusions and recommendations for further work

The purpose of this thesis was to develop a method that supports value balancing of customer requirements and costs in the concept phase of the product development process at VCC. The study aimed to develop a method that provides product development teams at VCC with reflection on how cost, technical characteristic, and customer requirements effect the end-product. The goal was to develop a method utilizable for achieving a value-optimized balance of the products. This goal has been achieved by changing, combining and adapting various theoretical models and methods addressing different parts of the value-balancing in product development problem to the specific conditions in the product development process at Volvo Car Corporation. Further, the proposed method has been adapted to current routines at Volvo Car Corporation and when necessary, new routines have been suggested. Therefore the Value Balancing Method is fully implementable at Volvo Car Corporation.

The Value Index Chart provides an illustrative overview of the relative importance in comparison to relative cost. The information from the chart can be used to study which systems that need to be functionally improved and which that need cost reduction effort. This chart therefore provides sufficient information to perform value balancing. The chart can also be used to visualize how changes in system affect the overall balance.

The modularity matrix provides valuable information of which systems that should be platform systems and which that ought to be product specific systems. The matrix further identifies strategic important systems that are important to customers and have high costs simultaneous. These systems need careful strategic analysis.

The critical-few matrix identifies attributes that are most important to customers and that are technically provided by high-cost systems. These attribute areas and the systems that technically provide the attributes need extra management attention in order to enable a successful product development.

To conclude, the Value Balance Method would be a valuable method to use at VCC since it address and provide valuable information and decision support for critical areas of the product development process, i.e. value balancing, platform decision support, and identification of critical attributes and systems.

The Value Balance Method does not provide output data that can be used as technical specifications of the product. Instead, the output data provides general data at an overview level to support the product development team in the holistic and complex situation of product development process at VCC. Because of the simplicity of the method there is no need of specialist knowledge to understand the different parts of the method. Therefore it will enable collaboration and communication in cross-functional product development teams at VCC.

Criticism to this thesis could be that focus many times has been to use existing data and theoretical models has been changed sometimes rather widely in order to be adapted to current procedures and routines at VCC. Although this has been argued to be necessary, a more objective academic point of view of input data could have been discussed. However, since the purpose was to deliver a method that is actually possible to implement at VCC this focus has been secondary. Therefore, input data of sufficiently quality has been used rather than theoretically preferred data.

Further work needed for the method is first of all incorporation of the data from the Attribute Balance Study. The method also needs to be tested, preferably simultaneously as existing methods, in the product development process at VCC. It would also be interesting to actually test the method with historical data. The testing of the method would provide valuable information of how to fine tune the method in order to improve its accuracy and validity.

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Appendix I – Interview questions

Each interview starts with an introduction to the thesis in order to give a contextual meaning to our questions. The introduction is always the same in order to achieve standardization of the interviews. The introduction is:

"We are developing a method that allocates product attributes to technical systems. The product attributes are ranked by customers and by using a technique similar to QFD each system can be assigned a relative importance value". The respondent is shown a schematic illustration of the house of quality. *"By comparing the relative importance of each system with its relative cost, a value index is composed".* The respondent is shown an illustration of a value index chart. *"Systems that are not within the given limits should be changed. In order to understand the efforts needed to change a system's position in the value index chart, a cost of change classification of the systems will be implemented in the method. We define cost of change as the cost of implementing a new or changing an old technical system when constructing a new car. The cost of change for individual systems should not be considered in correlation with other systems".*

Interview questions

What affects the cost of change?

What would you use to compare the cost to change the system between different systems?

Which groups of costs should be included when you compare the cost to change a system?

Would it be possible to do a general ranking of systems according to their costs of change? And if yes, which or whom could perform that ranking?

Do you think that the complexity of the system is a good measure for the cost to change the system?

If yes, what is complexity for you?

Of those mentioned, is there one or several of them that is a good measure of complexity?

Interview questions in Swedish

The interviews were conducted in Swedish and therefore the questions are presented in Swedish as well.

Vad påverkar förändringskostanden?

På vilka grunder skulle du jämföra förändringskostnader mellan system?

Vilka kostandsgrupper bör ingå om man gör en kostnadsmässig jämförelse av förändringskostnader?

Skulle det vara möjligt och om ja, hur kan man göra en generell ranking av system efter förändringskostnader?

Är systemens komplexitet ett bra mått på förändringskostnader?

Om ja, vad är komplexitet för dig?

Finns det någon/några av dessa som var och en för sig eller tillsammans ger ett bra mått på komplexitet?

Appendix II – Databases and search words

Databases:

- Business Source Premier
- CHANS
- GUNDA
- JSTOR
- LIBRIS
- Science Direct

Search words:

Component sharing

Conjoint analysis

Cost lock-in

Cost of Change

Customer requirements

Customer satisfaction

Decision support tools

Product Development

Product platforms

Quality Function Deployment

Target costing

Value based decision making

Value index

Value optimization

NOTE: The search words has been altered and modified to capture similar notations.

Appendix III – People interviewed for the explorative study

Lennart Rosendahl, Manager Complete Vehicle 91220

Kjell Månsson, Finance Manager 50340

Kurt Falk, Functions & Attributes Complete Vehicle 91900

Ingvar Arlenby, Cost Engineer 91900

Christer Karlsson, Controller 90420

Mats Ajoudan, Cost Engineer 91900

Lars Stenvall, Concept Engineer 91220

Anders Horvallius, Finance Manager 53050

Appendix IV – Definition of attributes at EB-level

The definition of attributes at VCC:

- **Passive Safety,** that means protection against the risk of human injury at collisions (e.g. via strong vehicle body, airbags, seat belts, etc.)
- **Active Safety,** that means systems that reduce the risk of being in a collision like ABS brakes, stability systems, good lightning etc.
- **Security,** that means systems that help to prevent burglary or car theft like alarms, security glass, door locks etc.
- **Fuel consumption,** that means impact on cost and refill frequency.
- **Clean interior,** that means clean air inside the vehicle, e.g. via filters for pollen, soot and gases, toxic free materials and easy to clean.
- **Materials and recycling,** which means reduction of materials that can harm environment. And furthermore, saving of global resources by recycling etc.
- **Dependability,** that means no failures and things function properly over time.
- **Solidity,** that means rigid, solid quality feeling when closing doors, using handles and switches etc and no squeaks and rattles.
- **Design quality,** which means fit & finish, material quality and colour harmony/matching.
- **Exterior Styling,** that means looks of the car outside.
- **Interior Styling,** that means looks of the car inside.
- **Handling,** that means precise and responsive steering, high directional stability, good manoeuvrability with small turning circle.
- **Noise Comfort,** that means low and balanced engine-, road-, and wind noise and with a pleasant sound character.
- **Driveability,** that means smooth engine and transmission. Jerk free gear shifting and ease of speed adjustments.
- **Ride Comfort,** that means smooth ride in comfortable seats and with good wheel suspension.
- **Performance,** that means acceleration and engine response, power and pick up when needed, e.g. for quick overtaking.
- **Roominess,** that means interior roominess and luggage/cargo space.

- **Ergonomics,** that means reach ability, understanding of controls and displays, all-round visions, getting in and out of the vehicle.
- **Climate Comfort,** that means pleasant interior climate and mist free screens regardless of ambient conditions.
- **Daily life usage,** that means all functions and features that supports you in your practical usage of your car like interior flexibility, storage, refuelling, eating & drinking etc.
- **Information and entertainment,** that means information and entertainment through radio, CD player, navigation systems, wireless communication etc.
- **Running costs,** which mean repair, maintenance, insurance cost, but excluding gasoline.

Appendix V – Product Structure Systems

Listing of the 37 Product Structure Systems:

Engine mounting

Fuel

Exhaust

Engine air distribution

Engine cooling

Brake

Pedals

Wheel suspension

Wheels / tyres & equipment

Steering

Vehicle dynamics

Interior trim

Seats

Instrument panel

Climate system

Restraint

Lighting

Cleaning

Door mechanism

Glass / mirror

Roof and convertible

Door structure & seal

Rear opening

Service lids & front fender

Body covers

Bumper&Spoiler

Body structure

Paint & surface treatment

Petrol Engine

Automatic Transmission

Driveshafts

Powertrain control

Electrical architecture

Comfort & driver information

Security & body electronics

Safety electronics

Infotainment

Appendix VI – Reports from ProCost

There are seven different cost control reports available from ProCost. The first type of report is Assortment Report, which gives a snapshot that reflects the actual situation in the different systems a specific week. The second type of report is called Cost Estimate Report and provides summations of the cost estimates from complete vehicle level down to part number level. In the third, called Delta Report, it is possible to compare costs in two different Cost Estimates Report-issues between two dates. The fourth report, Logbook Report, shows the product cost history where all cost changes and associated comment are logged. The next kind of report is EXCEL Reports which gives the possibility to analyse and present ProCost-data, both Unit Cost and Facilities & Tooling, in a customised way in Microsoft Excel. The sixth kind is called PSS Report and offers the opportunity to view ProCost data from several projects in the same report. The PSS Report can either present Product Costs per PSS area or Facilities & Tooling by PSS or as Payment plan over Appropriation plan and can also be exported to Microsoft Excel. The seventh report is Graph Reports and presents Unit Cost and Facilities & Tooling as a trend curve in a diagram.

Appendix VII – People interviewed

People interviewed for cost treatment at VCC:

Håkan Bråvi, Manager Cost Estimators 53015

Christer Karlsson, Controller Product Cost Control 90420

Birger Svensson, Commonality Manager 56200

Ingvar Arlenby, Cost Engineer 91900

Jan-Olov Lundgren Project Leader EFT 90400

Pernilla Krook, Product Planning 56300

Appendix VIII - Allocation Method

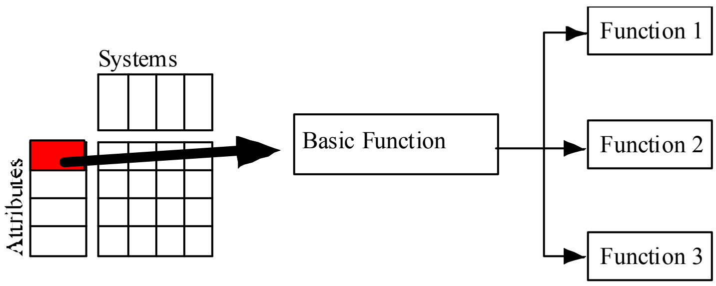
This is an extract from Söderqvist’s (2004) thesis.

Purpose

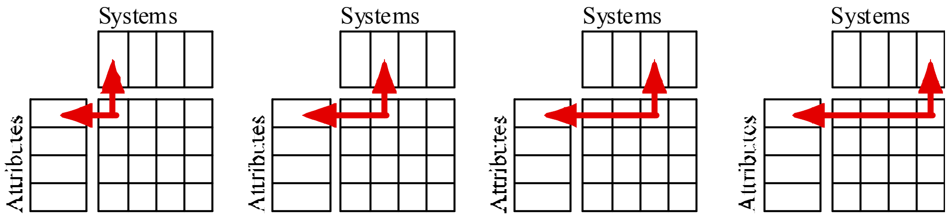
The purpose of the allocation method is to improve the allocation between attributes and systems in the original QFD-matrix. This is achieved by creating a function tree for each FKB area. The first level of the function tree defines the basic function of the FKB area and the subsequent functions describe how this overall function is achieved. To each secondary function the PSS systems are linked by primary, secondary and tertiary contribution.

Procedure

The allocation procedure starts with defining the basic functions for the FKB area. The basic function should define how the complete vehicle satisfies costumer need. The basic function could be "reduce passenger injury" for the crashworthiness FKB area. The second step is to identify important functional demands that have to be fulfilled in order to reach the overhead function. These demands are stated as functions in the second step in the hierarchy. The functions should preferably be as a verb-noun pair, e.g. "control passenger impact load", see figure below.



The third step in the process is to determine each systems contribution to the functions, which is performed step by step in the matrix, see figure below.



The relative functional contribution of each system to each of the functions is categorized in the following groups:

- Primary: The system is primarily designed to perform this function. E.g. the brake system has a primary contribution to the function *provide braking torque*
- Secondary: The system is partially designed to perform this function in cooperation with other system and has a smaller contribution compared to the primary system(s). E.g. the wheels and tire system has a secondary contribution to the function *provide braking torque.*
- Tertiary: The system is not originally designed to perform the function but has an indirect effect or contribution to the function. E.g. the engine system has a tertiary contribution to the function *provide breaking torque* by generating vacuum to the brake servo.

Each system can only have one type of connection to each function but can have connections to several functions.

The fourth step is to calculate the relative importance of each system to the basic functions. This is achieved by assigning weights of 9,3 and 1 to primary, secondary and tertiary contributions. The weights from each function is added together and converted to relative values by dividing by the total number of weights assigned to the basic function. By weighting together several functions for each FKB area its possible for systems to achieve a higher relative score compared to regular QFD allocation. This is especially important when there exists a high number of medium and weak connections in order to attain an accurate score.

Example

The following example is made for the FKB area *brake performance*. Basic function is defined as *enable controlled and effective braking.* From the basic function two important functional demands are identified and stated as functions. Systems are categorized by contribution to each function of the two functions:

1 Provide braking torque

- Primary: Brake
    - Secondary: Wheels/tyres and Pedals
        - Tertiary: Engine

2 Control Stability

- Primary: Brake and Vehicle Dynamics

- Secondary: Pedals (Feedback)

The resulting relative weights are calculated and are presented in the table below.

System	**%**
Brake	48,6
Vehicle Dyn.	24,3
Pedals	16,2
Wheels/Tyres	8,1
Engine	2,7
Sum	100,0

Appendix IX – Main Matrix

		100%	100%	######	######	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	####
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NOTE: All information in this matrix is hidden due to confidentiality arrangements.