CHALMERS

Development of Customized-to-Order Products

Background, Challenges and Managing Strategies

A Case Study of Volvo Buses

Master of Science Thesis in the Product Development

MUKUL LAGU

Department of Product and Production Development
Division of Product Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2012

Master of Science Thesis

Development of Customized-to-Order Products

Background, Challenges and Managing Strategies

A Case Study of Volvo Buses

MUKUL LAGU

Division of Product Development
Department of Product and Production Development

CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2012

Development of Customized-to-Order Products

Background, Challenges and Managing Strategies
A Case Study of Volvo Buses

MUKUL LAGU

Contact information:
mukul@student.chalmers.se

Division of Product Development
Department of Product and Production Development
CHALMERS UNIVERSITY OF TECHNOLOGY
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Göteborg, Sweden 2012

Development of Customized-to-Order Products

Background, Challenges and Managing Strategies

A Case Study of Volvo Buses

Abstract

This thesis is conducted in cooperation with the Project Management Support department at Volvo Buses and Chalmers University of Technology in Göteborg, Sweden. The overall purpose of this thesis is

'to explore the background for product customizations in Customized-to-Order products, identify the challenges for core business processes as well as overall organization and finally in this context evaluate applicability of modularization strategies with possible implications.'

In order to fulfill this objective, the author conducted six months of qualitative case study research at Volvo Buses. The research was initiated with a broad focus to understand the past and current developments in the bus industry, the associated sales process, Volvo Bus's products, the global markets and their contribution towards product customization requirements. By taking a number of interviews the author identified, described and analyzed the challenges for Volvo Bus's core business processes and overall organization due to the product customizations. In parallel to this research the author evaluated the applicability of modularization strategies to overcome these challenges and to efficiently provide customized variety of products. Part of this thesis also elaborates efforts done by Volvo Buses to address the customization issue both externally and internally, and discuss their progress.

The thesis concludes with recommendations for reducing customizations upfront in the sales process and for improving the success of the current efforts being made to implement modularization strategies. The implications of these recommendations on both Volvo Buses and its customers are also discussed. The findings and recommendations of this thesis are not necessarily specific to Volvo Bus's and could be relevant for all similar companies developing Customized-to-Order products.

Keywords: Product Development, Customized-to-Order, Product Customization, Modularization Strategies, Challenges, Volvo

Acknowledgements

Having the opportunity to conduct this study at one of the world's leading manufacturer of buses has been like a dream come true for me. The knowledge gained during these six months in the field of product development with such an esteemed organization will surely benefit in my future professional life. For this reason I would start with showing my acknowledgement to the Volvo Buses for their openness and willingness to support the students.

I would like to thank all the people at Volvo Buses for their help and collaboration during this endeavor, particularly to my company supervisor Fanny Josefsson for believing in me from the start and giving me this opportunity. Also I wish to express my gratitude to my academic supervisor, Researcher Lars Almefelt for his continued encouragement and invaluable suggestions during this thesis.

My special thanks go to my wonderful family for the support and encouragement they have provided me throughout this thesis and two years of my master's studies. Aai, Baba, Palla even though you are far away you are always with me in the spirit.

I am indebted to my best friends Ragini and Somak for their support, dedication and understanding without which I would be lost. Last but not the least, special thanks to all the desi gang Nilesh, Govind, Vamsi, Lobhas, Sunny and Gaurav for making me feel home away from home.

Mukul

Göteborg, June 18th, 2012

Table of Contents

List of Figures

List of Tables

1. Introduction

This introductory chapter presents the background and focus of this thesis. It also presents the problem description in relation with Volvo Buses, followed by the purpose and number of research objectives. It explains the overall thesis approach and concludes with the scope and delimitations of this thesis.

1.1 Background

In a current competitive environment that is global, intense and dynamic, companies that get to market faster and more efficiently with products that are well matched to the needs and expectations for target customer create significant business leverage (Wheelwright & Clark, 1992). When customers are making a single choice in product class they value the variety only to the degree that it provides the single option they desire, thus their goal is to cutting through variety and locate their optimal choice (Kahn, 1997). In case of products which are very complex, expensive and having large variety can only be produced after receiving a firm customer order. For such products customers are deeply involved in specifying the product as per their requirements making every product customized to order. In addition to this, if these products are sold globally in different markets, there could be additional customization requirements due to the legal standards, competition, localization needs etc. Although product customizations might be used to justify increased prices and high margins, companies should strive to provide them at optimal cost, since in some industries even a high level of customization does not justify increased prices (Piller, 2007)

Thus in their quest to manage product variety, companies in most industries are increasingly considering product development approaches that reduce complexity and better leverage investments in product design, manufacturing and marketing (Krishan & Gupta, 2001). Modularization strategies, i.e. building of a product from smaller subsystems that can be designed independently and assembled into highly customized final products, appears as successful strategies to create customized variety with an efficient use of resources. (Robertson & Ulrich, 1998) (Persson & Åhlström, 2006). The advantages of these strategies include increased speed in product development, reduction in product development cost, increased product reliability, increased variety, reduced complexity and increased flexibility. But adopting such strategies is argued to be among the most important decisions for a company. So before implementing these strategies a careful analysis of both internal and external scenarios for a company is necessary to be carried out.

1.2 Problem Description

Volvo Buses is one of the world's largest manufacturers of heavy buses. It offers a complete range of products to meet diverse customer requirements for passenger transport solutions. The product range includes complete city buses, inter-city buses, coaches as well as bus chassis. It is complimented by comprehensive telematics and aftersales services.

The commercial transport industry especially for buses is characterized by Customized-to-Order products for each customer order. As Volvo Buses are sold globally, different customizations are needed to fulfill various legal, environmental and country/city specific customer requirements. It is also important to introduce product upgrades at regular intervals to retain the market position and premium brand value. This has resulted in large number of product variants which takes considerable amount of development time and incremental costs. At the same time as the overall sales volumes are low, there is higher need of synergies across the range of products to achieve economies of scale and be a profitable and competitive player in the market segment.

Modularization strategies i.e. competing with multi product strategy based on product families sharing interchangeable modules with standard interfaces has proved to be successful for many companies in commercial vehicle industry e.g. Scania. Even though these strategies have been in discussions at Volvo Buses for few years, it has yet to catch a significant attention in overall development processes. Now as the company is getting ready to implement lean product development through a group wide initiative to improve the research and development efficiency (RnD30), it is imperative that these strategies get much more focus and attention. But before jumping to these strategies it is beneficial to get a holistic view of existing situation, understand the evolution of business, market and customer requirements that drive the need for customization. Also a careful analysis of the current challenges faced by different functions of the company could provide valuable inputs for checking the applicability of these strategies. As the company already tried to implement these strategies before, it would be necessary to know their progress and discuss the reasons for success or failure.

1.3 Purpose & Objective

Based on the background and problem description the following thesis purpose was formulated

The purpose of this thesis is to explore the background for product customizations in Customized-to-Order products, identify the challenges for core business processes as well as overall organization and finally in this context evaluate applicability of modularization strategies with possible implications.

To support the purpose the following research objectives were set:

- Explore the background behind product customization by analyzing overall bus business, Volvo Buses global markets and customer perspective.
- Summarize degrees of required customizations on current products.
- Identify challenges due to customization on core business processes and organization.
- Evaluate applicability of adopting modularization strategies.
- Investigate current and past efforts being done to tackle this issue and their progress.
- Give recommendations for insuring success of those efforts.
- Discuss the implications of recommendations for Volvo Buses and its customers.

1.4 Thesis Approach

To achieve the research objectives of this thesis, the author initially started the secondary research with help of trade journals and academic literatures to build a knowledge base regarding product customization, different managing strategies and their implications. At the same time the author also explored Volvo Buses through Volvo intranet, informal interviews and direct observations. The purpose was to get a clear background about the company, organization structure, products, processes and general views pertaining to the thesis objectives. Based on these findings an interview guide was designed to collect an extensive empirical data. The findings from this data collection were analyzed and discussed in combination with previous literature studies. Applicability of modularization strategies was also evaluated in parallel. Finally the author concluded this thesis with the future recommendations and their implications on Volvo Buses and its customers.

1.5 Scope and Delimitations

Pertaining to time restrictions for the thesis and for keeping focus on research objectives the following limitations were set:

- All the observations and interviews for data collection were done internally within Volvo Buses. Direct interactions with the customers or sales process were not undertaken.
- The focus was on overall strategy; specific studies regarding component or system modularization are not intended in this study.
- Excludes creation of new process; however it does not prevent from giving recommendations to improve existing processes or implement processes identified in literature research.

1.6 Outline of the Report

The layout of the thesis is based upon the general thesis guidelines published by Chalmers University of Technology. As the thesis results are very extensive, for easy reading and understanding, the results and discussions are grouped in three different parts. The following outline is used in this thesis. It consisting of ten main chapters

- Introduction – *Background, problem description, purpose, approach and scope of the thesis*
- Presentation of Volvo Buses – *Products, organization and type of development projects*
- Theoretical Frame of References – *Product customization, modularization strategies*
- Thesis Methodology for Data Collection and Analysis – *Case study and interviews*
- Results and Discussions I – *Background bus business, Volvo Buses, Market regions*
- Results and Discussions II – *General views and challenges for core business processes*
- Results and Discussions III – *Past and present efforts with their success/failures*
- General Discussions – *Discussion about thesis methodology and results*
- Recommendations and Implications – *For Volvo Buses and its customers*
- Conclusions and Future Research – *Way forward*

2. Presentation of Volvo Buses

This chapter provides a brief description of Volvo group and Volvo Buses. This information together with an introduction of Volvo Bus's products, development organization and type of development projects will provide the background information that is needed for the analysis and validity of this thesis.

2.1 Volvo Group and Volvo Buses

The Volvo Group is one of the world's leading manufacturers of trucks, buses and construction equipment, drive systems for marine and industrial applications and aerospace components. The new organization structure effective from 1st of January 2012 is shown in figure 1.

Figure 1: Illustration of Volvo Group Organization (Volvo Buses Presentation, 2012)

In this new organization Volvo Buses is placed under business areas together with Volvo Penta and Volvo Aero. With approximately 8000 employees and plants situated worldwide it is one of the world's largest manufacturers of heavy buses and bus chassis.

2.2 Volvo Buses Products

As mentioned in the introduction Volvo Buses offers a broad range of passenger transport solutions to match the diverse customer requirements. The product offer can be classified into three segments, city, commuter, coach. Volvo Buses offers either a complete bus or just a chassis in all these three segments. Bus chassis customers can select one of the external body builders with which Volvo Buses

cooperate. Each of the three segments contains the range of models/variants. In terms of the standard offering of a product, there is no standard specification as such. There is only a rough specification attached to each model/variant combination and it is changed depending upon the customization needs of every order. Figure 2 represents the common products offered by Volvo Buses. For the location wise complete product portfolio please refer to Appendix I

.

Figure 2: Volvo Buses Products: Coach, City/Intercity bus and bus Chassis

2.3 Volvo Buses Development Organization

To manage the different customers' need worldwide, Volvo Buses *Global Marketing* organization is divided into three business regions – Europe, Americas and International. Each business region gives input to the *Global Product Planning* organization with their unique market requirements. *Global Product Planning* in turn gives input to the *Project Management* Organization within *Global Product Development* for initiating new development projects. *Global Product Development* also consists of *Global Engineering* comprising of different development teams arranged according to different product systems, e.g. BiW, Powertrain, Electricals, and Telematics etc. Until recently most of the product development projects were located in Göteborg Sweden. But now to reduce the development cost and gaining local knowledge of markets the company is trying to expand the global development footprint. For this the company is in the process of ramping up the product development organization both in the region Americas and International.

Since all the projects are more or less unique, the project organization for each project is slightly different. Typically a project has a Chief Project Manager (CPM) responsible for overall project. Additional Project Managers (PM) from different functions of the company e.g. purchasing, aftermarket, manufacturing report to the Chief Project Manager. Actual development work is carried out by the line organization in *Global Engineering*. A Technical Project Manager (TPM) coordinates these developments within *Global Engineering*. A Project Assurance Manager (PAM) and a Requirements Manager (RM) support Chief Project Manager.

2.4 Types of Development Projects at Volvo Buses

There are mainly two different types of product development projects at Volvo Buses, both with the different amount of activities and resource involvements. These are called 'Start Cost Projects' and 'Maintenance Projects'. Start cost projects have an important product impact and the result is often an additional new product to existing portfolio. The second development project type carried out at Volvo Buses is maintenance project, also known as Product Modification Request (PMR). These projects are smaller and carried out for up gradation/facelift of existing products that are usually in production.

There are also the third types of product development projects which do not come under *Global Product Development*. These are small customer adaptations required for every order. Some of these customer adaptations need some development work and it is carried out locally at each manufacturing location. These are supposed to be the one time developments for that particular order. This *Customer Adaptation* organization reports to *Global Manufacturing* and directly interacts with respective marketing organization.

3. Theoretical Frame of Reference

This chapter presents theoretical frame of reference behind this thesis. The information presented is mainly collected through the secondary research. This will provide the knowledge that is necessary to investigate and explore the thesis objectives.

3.1 Product Customization

Product customization can be defined as producing a physical good or a service that is tailored to a particular customer's requirement. Rapidly evolving technologies, global competition and more assertive customers are leading companies towards customization of their products and services. (Lampel & Mintzberg, 1996) (Ramdas, 2003). In their desire to become customer driven, many companies have resorted to inventing new programs and procedures to meet every customer's request. As customers and their needs getting increasing diverse such an approach is a sure way to add unnecessary costs and complexity to the operations. (Gilmore & Pine, 1997). The paradox of the modern enterprise is that it must reduce costs while offering a much richer product variety to its customers than never before. (Hvam, 2008). In the extreme each and every option offered could be unique. But such high customization strategies could backfire if customer does not know his own preferences and get overwhelmed by available choices. Then it is a role of marketer to help their non-expert customer to figure out which options best fits his need. The more customer become partner in this process he is more likely to be satisfied with his final choice. (Kahn, 1997).

3.1.1 Customization Approaches

In practice most of the manufactured products available in market do not belong to the two extreme poles of fully standardization and fully customization. Instead they can contain both customized and standardized elements that place them in between the poles (Gallardo, 1995). To help the managers what type of customization they should pursue, (Gilmore & Pine, 1997) identified four approaches to customization i.e. collaborative, adaptive, cosmetic and transparent. Based upon different situations these approaches can be used either individually or in combination. These are illustrated in Figure 3.

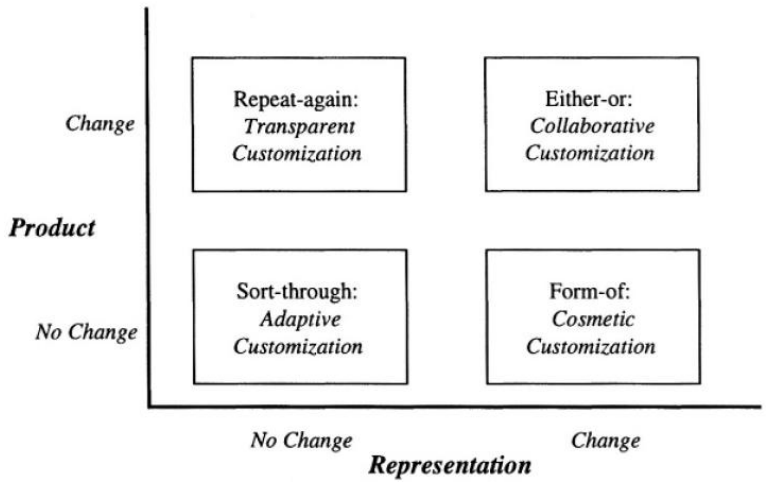

Figure 3: The Four Approaches of Customization (Gilmore & Pine, 1997)

Adaptive Customization offers one standard but customizable, product that is designed so that users can alter it themselves. It is a promising alternative when the possible combinations can be built into the product e.g. adjustable office chair. *Cosmetic Customization* presents a standard product differently to different customers, company should adopt this option when its standard product satisfies almost every customers and only products form needs to be customized e.g. curtain fabric that could be cut based on every customer's needs. *Transparent customization* provides individual customers with unique goods or services without letting them know explicitly that those products and services have been customized for them. Of course this attribute requires a business to have luxury of time to deepen the knowledge about the customers e.g. personalized service in hotel by monitoring customer's usual choices. Finally *Collaborative Customization* conducts a dialogue with individual customers to help them articulate their needs, to identify the precise offering that fulfills those needs and to make customized products for them. It is a good approach when each customer has to choose from a vast number of elements or components to get the desired functionality or design e.g. custom made furniture.

Thus a company could offer a choice from a set of ready-made offerings, or in contrast fully customize product on individual specification. Middle strategy *customized standardization* partially customizes a product based on standard set of components or allowable features. The degree of customization should be driven by a combination of what the market values and company's own development, manufacturing and supply chain capabilities. (Ramdas, 2003) (Lampel & Mintzberg, 1996)

3.1.2 Customization of Complex Products

Differentiating between simple and complex products is not very self-evident. (Persson & Åhlström, 2006), (Holmqvist & Persson, 2003) Summarize different parameters that define complex products as illustrated in Figure 4. These parameters could be used to compare any two products. The more number of parts, strong interdependencies between modules, varying technologies, and complex functional to physical mapping characterize a complex product.

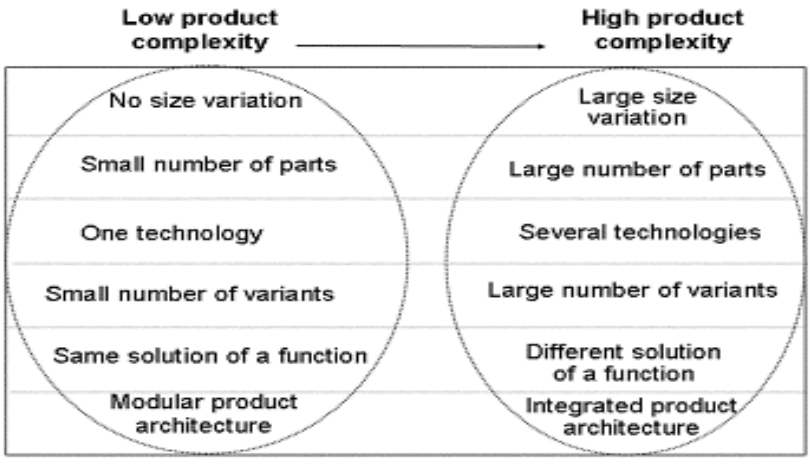

Figure 4: Parameters for Product Complexity (Holmqvist & Persson, 2003)

Examples of complex products could be found in industries such as pulp and paper machinery, steam turbines, flight simulators, heavy commercial vehicles and many more. In these cases individual customer can be deeply involved in every aspect of the transaction and expects key product decisions to be negotiated jointly (Lampel & Mintzberg, 1996). These decisions could be influenced by variety of internal and external factors and requires either designing the product from scratch or multiple product adaptations as per customer requirements. Constant upgrades and reconfigurations of these products are necessary for long term share of the customer and extending product life cycle. Thus for complex products, customization requirements upfront for the original product and coping with changing requirements over the product lifecycle are closely interrelated and equally important. (Hvam, 2008). This demand of instant integration of rapidly changing or diverse customer requirements calls for higher strategic flexibility. (Sanchez & Mahoney, 1996). Most of the flexibility is determined by how the physical product is built, organized and interactions between different functions of the product.

3.2 Product Architecture

Product architecture determines how the product can be changed both within life of a particular artifact and across generations of the product (Holmqvist & Persson, 2003). Product architecture can be defined as "(1) the arrangements of functional elements; (2) the mapping from functional elements to physical components; (3) the specification of the interfaces among interacting physical components" (Ulrich K. , 1995) illustrated in Figure 5

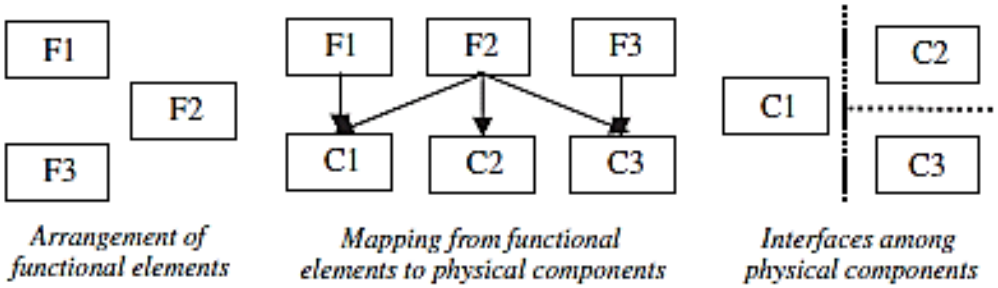

Figure 5: Illustration for Definition of Product Architecture (Ulrich K. , 1995)

Product architecture can be divided into modular architecture which includes one to one mapping from functional elements to physical components (see Figure 6) and integral architecture which includes a complex non one to one mapping from functional elements to physical components (see Figure 7).

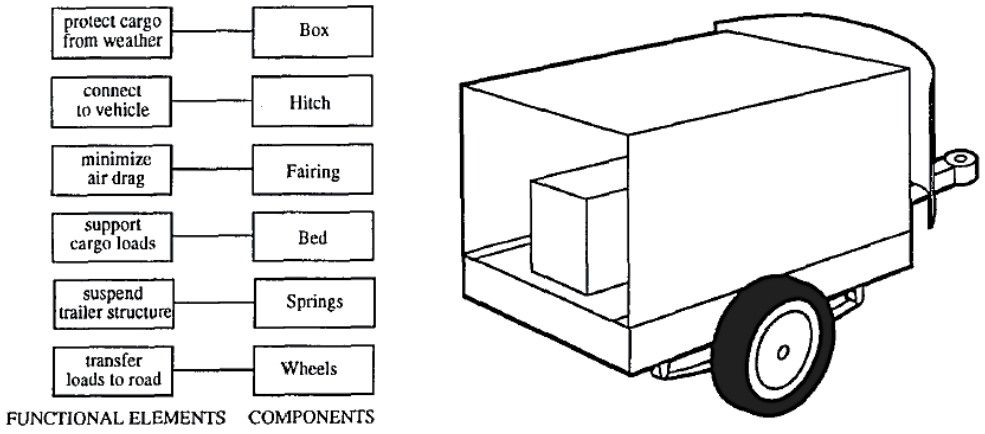

Figure 6: A Modular architecture with one to one mapping from functional to physical elements

(Ulrich K. , 1995)

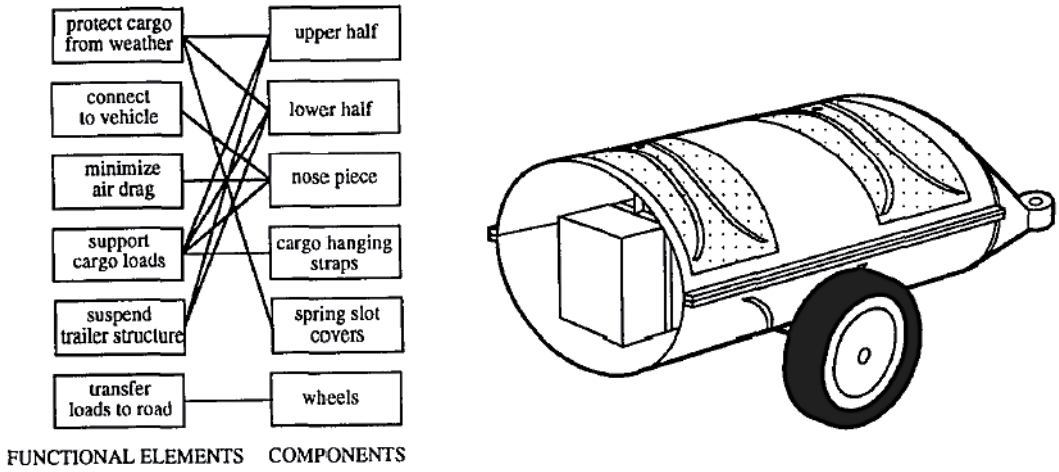

Figure 7: An Integral architecture with complex mapping from functional to physical elements

(Ulrich K. , 1995)

Product architecture decisions are argued to be most important decision taken by company (Robertson & Ulrich, 1998). To effectively manage product architecture two main concepts emerge, product platforms and product modularization.

(Robertson & Ulrich, 1998) Define platform as "the collection of assets that are shared by a set of products." These assets are divided in four categories.

- Components: e.g. the part designs of a product, the fixtures and tools needed to make them.
- Processes: The equipment used to make components or to assemble components into products and associated design of production process and supply chain.
- Knowledge: Design know-how technology application, production techniques, testing methods.
- People and relationships: teams, relationships among team members, within organization and with suppliers.

(Meyer & Lehnard, 1997) Define platform as "a set of subsystems and interfaces intentionally planned and developed to form a common structure from which a stream of derivative products can be efficiently developed and produced."

(Sanchez & Mahoney, 1996) Define modularity as "a special form of design which intentionally creates a high degree of independence or 'loose coupling' between component designs by standardizing component interface specifications". On the same lines (Baldwin & Clark, 1997) define "modularization is the building of complex product from smaller subsystems that can be designed independently, yet function together as a whole." Modularization allows reduced task complexity and enhances the ability to complete tasks in parallel (Sanchez & Mahoney, 1996).

Initially the author started with exploring both of these approaches in context of the thesis objectives. During the process based on the findings by (Pasche, 2011) the author was able to differentiate between the two concepts and identify the appropriate situations they should be applied in. Product modularization is argued to be appropriate in situations where a broad variety is to be offered cost efficiently and where market dynamics demand constant upgrade of existing products. (Sanchez & Mahoney, 1996). (Garud & Kumaraswamy, 1995). This is judged to be the exact situation at Volvo Buses. In case of Volvo Buses due to the lower sales volumes the economies of scale claimed by platform approach are less significant. It is also difficult to justify the investments and resources required to design and maintain a stable platform. Taking that into consideration hence forth this frame of reference will primarily focus on theories related to different aspect of product modularization.

3.3 Product Modularization

Modularization is the process of making a product modular. (Sanchez & Mahoney, 1996) Define "Modularity is a special form of design which intentionally creates a high degree of independence or 'loose coupling' between component designs by standardizing component interface specifications". As per (Mikkola, 2000) "It is the opportunity for mixing and matching of components in a modular product design in which the standard interface between components are specified to allow for a range of variation in components to be substituted in the product architecture". According to (Ulrich K. T., 1991) "modularization depends upon Similarities between the physical and functional architecture of the design and minimization of incidental interaction between physical components." Minimization of interactions between physical components is made through standardizing interfaces (Baldwin & Clark, 1997). These interfaces are defined at the start of product development and are not allowed to change over specific amount of time (Sanchez & Mahoney, 1996) (Ulrich K. , 1995). As a result a wide number of products can be cost effectively derived from a limited number of components which can be combined and substituted for each other in a flexible manner (Sanchez & Mahoney, 1996).

3.3.1 Advantages of Modularization

In a heterogeneous market, modularization supports the challenge to produce the variety of products with limited resources and lower costs. During product development process, upgrades and maintenance are executed much easily if products are modularized functionally (Shamsuzzoha, 2011). A new model of existing product with some functional change could be developed by substituting specific modular components into the product architecture without having to redesign other components. This is called economies of substitution. (Garud & Kumaraswamy, 1995) (Sanchez & Mahoney, 1996). This easy upgradability forms the basis for providing the companies with the strategic flexibility needed to cope up with dynamic market situation and need for customized solutions (Baldwin & Clark, 1997).

Modularization allows reduced development task complexity and enhances the ability to complete tasks in parallel (Sanchez & Mahoney, 1996).Product modularization opens up alternative possibilities for decision making processes, since it enables decentralized decision making, coordinated by a set of clearly defined module interfaces (Baldwin & Clark, 1997). It also reduces time-consuming information processing and coordination cost for updating modules (Garud & Kumaraswamy, 1995). Companies can effectively utilize low cost development resources situated all over the world.

Modularization increases the component standardization, likelihood that a component is commonly used across range of products (Ulrich K. , 1995). Fully standardized interfaces also allow modules to be used across a range of products to achieve economies of scale and leveraging fixed investments over multiple products (Muffatto & Roveda, 2002)

By using the flexibility offered by modularization for product variation, a marketing organization can develop a more detailed knowledge of customer preferences for the product. This enables definition of new products in newly discovered market segments (Sanchez R. , Modular Architectures in Marketing Process, 1999). In case of complex expensive products, increased modularization can attract new customers by improved price/performance ratio, better quality and time of delivery. (Hvam, 2008).

At the same time each model-generation’s lifetime could be prolonged due to smooth modular upgrades within same generation. This helps to avoid costly peak work load in the development projects as only one module could be changed at a time. Modularization could help to decouple technology development from product development and reduce the uncertainties associated with it (Sanchez R. , 1999)

Modularization could also allow for the better exploitation of supplier capabilities by outsourcing a complete module and price negotiations based on larger volume per module (Ulrich K. , 1995). Significant reduction in manufacturing lead time can be observed because of the possibility to separately test and validate individual modules before final assembly (Shamsuzzoha, 2011).

Finally the greater reliability of reused component designs that have been incrementally developed over time may also help to reduce service costs and claims costs associated with new product introductions (Sanchez R. , 2002). It could also help in reducing variety of replacement parts in inventory and service staff training requirements (Sanchez R. , 1999)

3.3.2 Challenges for Modularization

The term modularization is used as a tool to break the product structure into smaller, manageable units which overcome the manufacturing complexity for developing customized products (Gershenson J.K., 2003). While implementing modularization approach, deciding on degree of modularization is a challenge because many times there are different views from marketing, product development and manufacturing. Here designers must know a great deal about internal working principles of overall products and processes to develop the design rules to make the modules function as a whole (Shamsuzzoha, 2011). Complex products are difficult to modularize completely due to the functional interdependencies exist, and that needs to be well coordinated on system level design (Persson & Åhlström, 2006) (Ulrich K. , 1995). Modularization needs a much higher level of knowledge and understanding about customers' exact desires and needs before its implementation (Shamsuzzoha, 2011). This demand for better systems engineering and planning tools (Ulrich K. , 1995).

Usually in modularization product variants are developed by adding, replacing or removing different pre developed modules or subassemblies. As the variants are made out of certain number of modules off the shelf it is possible that all products may look alike (Shamsuzzoha, 2011). So in industries where customer cares about product differentiation these similar looking products could damage customer satisfaction and cannibalization of companies own product offers (Ulrich K. T., 1991).

Modularity optimizes the local performance of a component by either using a standard supplied component or by enabling independent designed, tested and refined component. But it might fail to optimize the global performance of a product. E.g. If a product is made up of multiple optimized components instead of one integral component it could take more space or have more weight (Ulrich K. , 1995). It is often very cumbersome to integrate modules designed by different teams or locations and to make them optimally work together. Problems with incomplete or imperfect modularization tend to appear only when the modules come together and perform poorly as an integrated whole (Baldwin & Clark, 1997).

Another potential negative implication of product modularization is the risk of creating organizational barriers to architectural innovation (Ulrich K. , 1995). As the interfaces are fixed early onset of product development, the modular architecture allows components to change only in previously defined range of variation (Sanchez & Mahoney, 1996). This approach may also cause certain lack of

function sharing in design. (Shamsuzzoha, 2011). The design of interfaces and re design of existing interfaces consumes significant amount of time and cost (Muffatto M. , 1999).

3.3.3 Product Development Process for Modularization

Modularization encompasses the product development process used for developing modularized products (Ulrich K. , 1995). To exploit the benefits of modular product development, before implementing any modular design all the information and expected functionality of each module need to be collected at the early design stage (Shamsuzzoha, 2011). Breakdown of the product structure into modules requires significant planning and coordination between marketing, product development and manufacturing in order to meet customer requirements (Ahmad, 2010). It is also recommended involving potential customers, suppliers, distributors at the very beginning of formulating the modules based on target specification (Sanchez R. , 1999).

A basic product development process involves four phases, concept development, system-level design, detailed design and product testing and refinement. Modularization requires much more emphasis on system level design (Ulrich K. , 1995) . The process is illustrated in Figure 8

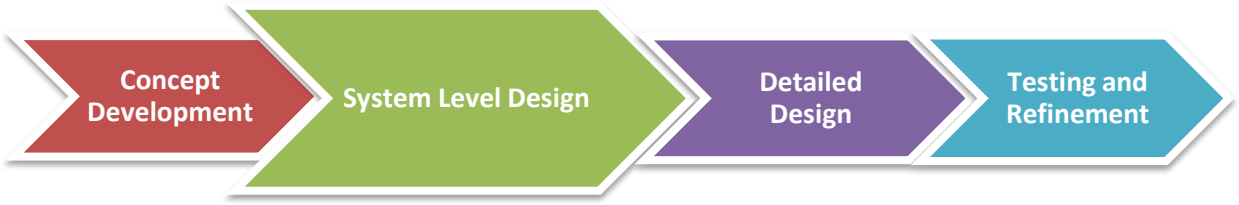

Figure 8: Product Development Process for Modularization (Ulrich K. , 1995)

Concept development – It includes selection of working principles of a product, the choice of functional elements, features and performance targets to match customer requirements.

System level design – During modularization the focus of system level design and planning is on carefully define component interfaces, specifying the associated standards protocols. Mapping of functional elements or features to product modules is done in this stage.

Detailed design – As the interfaces are already defined, for modular architecture detailed design of each component can proceed almost independently and in parallel. Management of design process focuses on module performance targets and interface specifications. It requires relatively less coordination between modules teams and individual modules can be tested and optimized separately.

Product Test and refinement – Final test and refinement is limited only to check the overall product performance as the individual modules are already optimized. Even if there are some performance issues those could be localized on particular module.

3.3.4 Modularity and Development Organization

Concept of product modularity is not only limited to product structure or product architecture as changes in product architecture also affects the organization (Henderson & Clark, 1990). Sanchez R.(2000) describes relations between product and organization architecture as "Products design organizations". Product modularity enables one to one mapping of product modules and organizational modules (Sanchez & Mahoney, 1996). Moreover, both product and organization have to be aligned so that technically separate components can be developed by technically separate organization (Sanchez R. , Modularity in Mediation of Market and Technology change, 2008). Consequently companies applying product modularization often develop a modular organization (Sanchez & Mahoney, 1996).

A modular product structure with standardized interfaces enables organizational processes to be independent and autonomous (Baldwin & Clark, 1997). Modularizing an organization based on intensity of coordination needs enables modules to react quickly to influences from the environment without influencing other modules (Thompson, 2007). Much of the product development work could be possible to conduct with reduced level of managerial authority, thereby reducing decision making overloads and delays (Galbraith, 1973).

On the other hand complex products are difficult to modularize completely, due to the functional interdependencies still exist (Persson & Åhlström, 2006). Therefor even though it is possible to design modular organization for such products, the output of these decentralized teams must be coordinated and integrated on some level (Baldwin & Clark, 1997).

This theoretical frame of reference provides a broad understanding regarding the product customization strategies, modularization and its advantages as well as challenges. Further it puts focus on product development process and organization perspective in relation with product modularization. These insights would be very useful while investigating current challenges and evaluating applicability of modularization strategies in context of Volvo Buses.

4. Thesis Methodology for Data Collection and Analysis

This chapter describes the methodology adopted for data collection and analysis during this thesis with rationale for choosing this method. The empirical data was gathered and analyzed from primary and secondary sources in a systematic manner and used to fulfill the thesis objectives. This chapter will also comment upon the validity and reliability as well as generalization of the collected data.

4.1 The Case Study

This thesis followed a qualitative case study methodology by performing a case study of Volvo Buses. Generally, the underlying rationale to apply case study approach is that it offers a full understanding of the nature and complexity of the complete phenomenon (Voss, Tsikriktsis, & Frohlich, 2002). To know the background and challenges during development of customized-to-order products and different managing strategies is a complex task. It requires a very broad perspective to understand the correlation between complex processes, internal and external factors associated with it. Since the primary information gathered was non-numerical and involved in-depth and extensive participation of a limited participant pool, qualitative case study method was best suited. Another reason for applying case study method was the explorative nature of this thesis. The case study method is the appropriate choice when the research area is relatively unexplored (Ulrich K. , 1995).

The inherent weakness of the case study approach is the limited generalizability of single case (Voss, Tsikriktsis, & Frohlich, 2002). But (Hamel, 1993) rejects these limitations and states that an individual case is the mandatory intermediary in attempting to grasp the common nature of individual actions and behaviors.

4.2 Empirical Data

The qualitative empirical data for this thesis was collected from a wide array of primary and secondary sources.

4.2.1 Primary Data

The primary data was collected by the author by keeping thesis objectives in mind. The primary data sources utilized in this thesis along with explanations are illustrated in table 1

Table 1: Primary Sources of Data

Primary Data Source	Explanation
Semi-Structured Interviews	Fully recorded and documented interviews with managers from Volvo Buses
Informal Interviews	Dialogs and informal conversations held throughout the stay at Volvo Buses. Recorded in thesis diary
Direct Involvement	Participation and observations during real working environment at Volvo Buses i.e. development projects

Interviews were of particular importance during the collection of primary data. The purpose of these interviews was to explore the views, experiences, beliefs and motivations of individual related to thesis objectives. Interviews are believed to provide a 'deeper' understanding of social phenomenon than would be obtained from purely quantitative methods such as questionnaires. Therefore they are most appropriate where little is already known about the study or where detained insights are required from individual participants (Gill, 2008). Thus it was thought to be the best strategy for this kind of thesis. Additionally informal interviews were carried out prior to formal data collection in order to formulate the most relevant questions.

With this is mind the author conducted total of 21 semi-structured, face-to-face and phone interviews throughout the course of this thesis. The selection of interviewees was carried out following a heterogeneous purposive sampling strategy (Robson, 1998). Majority of these interviewees were senior managers holding key positions in various function at Volvo Buses. Their inputs were essential in the exploratory, descriptive, and explanatory stages of the case study. Please refer to Appendix II for the list of the interviewees with their roles as well as the date of each interview.

The overall structure of the interview guide used in this study follows a commonly used sequence. As formulated by (Robson, 1998) the general sequence is: Introduction – Warm-Up – Main body of interview – cool off – closure. Semi-structured format was used to keep the focus during interviews and at the same time allow interviewer or interviewee to diverge or pursue an idea or response in more detail. Although a generic interview guide is used, the focus during the interviews was concentrated on the area where each interviewee had most knowledge. A framework of core business processes is used to gather, fill the gaps and mapping the information. The first two interviews were used as pilot interviews to refine the interview guide. Please refer to Appendix III for the interview guide. As the interviews were carried out by a single person it was important to record the conversation. Thus by prior permission of the participants all the interviews were recorded, transcribed and later deleted.

4.2.2 Secondary Data

Among the secondary data sources used in this thesis were Volvo Bus's intranet portal, previous relevant PhD, Master's Thesis, Trade Journals as well as academic publications. The secondary data sources utilized in this thesis along with explanations are illustrated in table 2

Table 2: Secondary Sources of Data

Secondary Data Source	Explanation
Volvo Intranet	Organization, processes, products, markets
Relevant PhD Dissertations, Master's Thesis	Theories, Methodologies and research contribution
Trade Journals and Academic Publications	Theoretical frame of reference, research related to thesis objectives.

4.3 Data Reduction and Analysis

The primary and secondary data collection methods gathered vast amount of information. Analysis of this information was a big challenge for the author. The analysis of the data collected from both primary and secondary sources was done in an integrated fashion. The transcribed interviews were reduced in line with the thesis objective, irrelevant data was omitted. A general scanning of interview data was made to pinpoint most significant findings. Major themes were identified and data was grouped accordingly. In some cases chain of events were constructed in order to understand the overall process from start to end. Throughout the process the intention was to gain a rich and multisided view about development of customized-to-Order products, its background and challenges. Those findings were then compared with the existing theories collected during the secondary research to evaluate applicability of modularization strategies.

4.4 Validity and Reliability

Validity refers to the accuracy of the information and its closeness to reality (Creswe, 1994). To increase the validity of the collected data different sources were used. Thus primary data collected through semi-structured interviews was supported by informal discussion and observations made during direct involvement in development projects. Reliability is concerned with degree to which a study can be repeated by another researcher leading to the same results (Yin, 2008).

To keep this in mind primary data was collected from credible individuals at Volvo Buses. All of them were having several years of experience working with Volvo Buses. The secondary data was also collected from trusted sources, Volvo Intranet and Chalmers electronic library.

To test the validity of the preliminary findings they were presented to a group of audience involved in product development projects at Volvo Buses. Important feedback and go ahead decision was taken before leading to final analysis and conclusions.

4.5 Generalization

The findings of this thesis are based on the single case study of Volvo Buses. The inherent weakness of the case study approach is the limited generalizability of single case (Voss, Tsikriktsis, & Frohlich, 2002). But still theory which is developed in case studies can be generalized to other cases which lie within the scope of that theory (Yin, 2008). In that case the findings for this thesis may be generalized to the companies with the following characteristics: Companies that develop and manufacture complex customized-to-Order products e.g. Train, Planes, Complex machinery, companies which operate in diverse global markets with varied customer requirements and finally companies looking for product architectural solutions to effectively manage their Customized-to-Order development.

5. Results and Discussions Chapter I – Product Customization Background

This chapter of results and discussions establish the background behind product customization in the bus industry from business and market perspective. This chapter begins with historical developments in the bus industry and its typical sales process, followed by Volvo Buses history and company's global market scenario. A side by side discussion clarifies how these factors drive the need for product customization. This chapter concludes with summarizing degrees of customizations and need for the strategic flexibility.

5.1 Historical Developments in the Bus Industry

Traditionally bus building was a build-to-order type local business where local body builders on town/ city level built the customized buses on truck or bus chassis provided by a couple of bigger manufacturers. In this setup those local body builders could be as lean as possible in terms of development, resources, and overall facilities. Thus they could offer maximum flexibility for any kind of product customization. A natural negative consequence of this setup was the lack of focus on verification/testing, inferior quality standards and poor aftermarket support. Over the years this structure had resulted in creation of local standards leading to fragmented and diverse product customization requirements, even between two cities in the same country.

If we try to understand the business situation, in city and intercity bus segment in Europe until mid-80's municipalities in different cities were handling their own public transport business. These public transport authorities (PTAs) were involved in planning, purchasing, operating and maintaining the buses and in most cases even specifying the engineering details up to nuts and bolts through in-house engineering departments. But then Margaret Thatcher government brought in the era of deregulations in UK which was quickly followed by many countries in Europe and during next decade almost every part of the world. In the new setup the role of PTAs was altered to specify cost of travel, ticketing system, routes and timetables, basic infrastructure and most importantly standard/specification of vehicles. The operations contracts were handed over to the private operators who own, operate and maintain the buses. Over the years this has resulted in bunch of big private operators in every county who owns a large fleet of buses and operates in different municipalities. E.g. in Sweden there were around 240 different municipalities running the public transport business but now after 20 years there are only 5 remaining, rest is taken over by private sector.

For long distance coach segment in most of the countries both PTAs and private operators run the bus service on different routes. The private operator could either be a small business owner running only couple of buses on single route or a large operator with multiple routes and operations all over the country.

So now we can say that the overall trend in the public transportation business is privatization and consolidation of smaller players into larger regional entities. These larger operators are looking for standardizing the specification for their entire fleet because of multiple benefits. First of all it will make possible to purchase large number of buses with similar specifications giving more power to negotiate the prices with bus manufacturers. Second, it will be easy to interchange the buses between the regions depending upon traffic scenario. One of the interviewee mentioned that today it costs around quarter of million SEK to put a bus from one region to another due to specification variations in painting, upholstery, fabric, ticketing system, telematics system etc. A third benefit is the standardization of operating environment and procedures for the drivers and technicians. So driving or maintaining any bus would be much easier. Another interesting perspective pointed out by interviewees is a general shift in focus from just purchasing cost of the buses to the life cycle cost which is a combination of initial cost, running cost, maintenance and servicing cost. Today, customers emphasize more on longer uptime of buses and demand for a quick service and spare parts availability.

If we look at bus manufacturers, before the privatization and consolidation started happening there were actually very few big companies who produced complete buses. The fragmented nature of market and small order quantities with very specific customization never qualified for an industrial mass production approach. But now as that scenario is changing, a lot of earlier chassis manufacturers have entered into mass production of complete buses on a global scale.

But the bus business is still a very traditional and conservative business compared to truck or car business. According to one of interviewees, as a rule of thumb in terms of accepting and implementing new processes or technologies truck business is 20 years behind car business and bus business is 20 years behind truck business. It means that major changes either in products or in business strategies do not happen overnight. To make bigger changes all the manufacturers might need to join hands and do lobbying to make it happen. So even though an individual customer appreciates a standard product specification for his whole fleet, that specification is valid only for that customer. Overall industry is still not mature enough to go for a standard of the shelf product offering. Looking at the past financial performances of Volvo Buses and other manufacturers' author can say that this business is infamous for generally low profit margins mostly because of higher investments and lower volumes. As today's bus manufacturers operate globally with multiple customers they face a challenge to efficiently provide customized products for each order.

5.2 Typical Sales Process in the Bus Industry

During investigation author identified that there is a fundamental difference in term of sales process for the buses compared to other automobile products. In regular automotive business most of the sales are through retail channels where customer specifies the vehicle out of predefined options and place an order. A small part of these orders could be special vehicles that needs some amount of customization

e.g. a taxi or a Police car. But in the bus sales process every order requires customization and it has a direct impact on complexity in this business. The following chapters explain the two common channels through which buses are sold.

5.2.1 Sales through Tender Business

Majority of the sales in city and intercity segment come from Public Transport Authorities (PTAs) or large private transport operators. The order quantities are significantly large and investments are huge. In case of PTAs it is public tax money and for private operators a huge capital investment, so the aim of the customer is to do a cost effective purchase without compromising on the product specifications. So they set an open tender document specifying the order quantity, product specifications, order lead time etc. and requests bids from the manufacturers.

The most important part of a tender is the product specification because it decides how much customization a product would need. The closer that specification to the already available products higher are the chances for the manufacturers to put a competitive bid (In terms of lead time and price) and still get a decent profit margin. There are number of factors which affect the product specifications in a tender document.

- Most of these customers already own a fleet of buses from a particular manufacturer. They want their drivers or technicians to drive or maintain any bus in the fleet, so they prefer not to buy products with different specifications. So it is extremely likely that the product specification is based on the existing products the customer already owns.
- Even if the market is deregulated and any manufacturer can bid for any tenders in any county, sometimes there is also a hidden political agenda/lobbying to favor local manufacturers. In this case specification in a tender document could be biased to favor a specific manufacturer, so other bidders have to customize their product.
- Lastly, as mentioned before the drivers and technicians are the important stakeholders in transportation business. In some cases just to show their influence the labor unions could put their own requirements in the tender specification.

To get the order manufacturers need to comply with the product specification in the tender document. As explained above, that product specification is influenced by lot of random factors and in many cases it does not match with the product specification manufacturer already has. It creates need for customization. Just to give the reader extent of impact e.g. whenever there is order created in Product Data Management system a tentative bill of material is generated based up on a closest available product specification. To make the customizations some part numbers are removed and modified parts numbers are added to the bill of materials. As per the geometric architect, in coach segment it could be 2 to 5 % but in city and intercity segment it could be up to 15 to 20%.

Manufacturers can try to steer the customer to set the tender specification fitting to existing products. Interviewees mentioned that the most practical option is to do lobbying with the customer before the tender opens for bidding. This strategy depends upon manufacturers past relations with that customer and convincing power. Even after the tender is allotted to particular manufacturer, further negotiations continue. Interviewees mentioned that as per their experience most of the times success of these negotiations is very limited. Customers hold all the important cards and even more last minute customization requirements get added into the tender specification.

5.2.2 Sales through Retail Business

In coach segment the buses are usually sold by the dealer in retail. Customers involved are normally small to medium size private tour operators. In a way it is similar to the activities at a car dealership, a customer choose a manufacturer, visits the dealer, describe what he needs, and get information about available product options. But it deviates further from this point. While specifying a car model the customer can only select from available combinations which are predefined by the manufacturer. In case of buses he can actually ask for something which is not available among standard option. Here this customer is actually making the purchase from his heart. One example given by one of the interviewees explains this very well. He mentioned "it is very likely that a customer, after having a long negotiation about product specification and price, could actually call in his wife or kids to make the final decision about some of the important aesthetic features."

Now if we try to analyze findings from above two chapters it underlines the deeply rooted culture of customization in the bus industry. Unlike the car industry where the manufacturers started and evolved with mass production systems, the bus industry was always been providing customized solutions. Majority of time the way buses are sold is mostly about providing a customer whatever he is asking for. Nevertheless there are some positive signs shown by the industry to go for a more standardize offer. But still for a global manufacturer like Volvo Buses the challenges posed by the customization issue are multifold.

In case of the tender business the important factor is how quickly the manufacturer can adapt the existing products to the tender specifications with proper quality and reasonable cost. Otherwise they might lose the tender to the competition. All the processes from order to delivery need to be fast and flexible. There is a very limited order lead time and in some cases the manufacturer is liable to pay the penalty to the customer for delayed delivery of buses. On the other hand in the retail business a customer has an attachment and perceived ownership for the product. So in addition to the customized products it is necessary to have proper differentiation between the products in terms of features or functions. In that way a retail customer would be satisfied by his own selection.

5.3 Historical Development at Volvo Buses

Volvo Buses started building buses on truck chassis during 30's. Over the years the company gathered a good experience of building specialized bus chassis. As explained in previous chapters, following business trend at that time, those chassis were used by local body builders in different countries for building complete buses. The main problem with that setup was lack of control over the quality and reliability of the final products delivered to customer. It was a conflicting situation because quality and reliability are the core values of Volvo brand. During 80's and 90's due to privatization initiatives by the governments many smaller transport businesses consolidated into larger entities with more mature demands. Getting a clue from this changing business scenario Volvo Buses acquired several body builders from different countries and started producing complete vehicles. But even then the approach was to take a Volvo Buses' European chassis and adapt/integrate that chassis to the local bodies. There are varying conditions in the different countries in terms of demands on product, labor cost, localization requirements and supplier capabilities. This has resulted in regional variation in the products, fragmented and sometimes duplicate development at different locations, and thus Volvo Buses lacked in a consolidated and globally coordinated industrial solution for producing complete buses.

Today Volvo is the second largest manufacturer of the heavy buses in the world. The buses are sold in more than 80 countries. In terms of product selling strategy, most of the interviewees agreed that flexibility in terms of customizing products for each customer order is the main selling point for Volvo Buses. Among top five global heavy bus manufacturers (i.e. Mercedes Benz, Volvo, MAN, Iris bus and Scania) Volvo Buses is recognized as the most flexible company. Volvo Buses seldom takes very big orders in Europe and deals mostly with small to medium orders with more customization requirements. One of the interviewees mentioned that Volvo Buses actually never sold a single bus without any form of customization.

Selling customized products in different markets with varying demands add too much complexity to the business. The support this hypothesis following section puts focus on global market scenario for Volvo Buses in terms of products offered, customization needs, competition etc.

5.4 Volvo Buses Global Market Scenario

Volvo Buses has three main market regions to manage the global range of products, sales, manufacturing and development.

Europe – North, west, south and central Europe
Americas – North and South America, Canada
International – Middle East, Africa, Asia pacific

Figure 9 taken from Volvo group annual report 2011 illustrates distribution of sales and revenue between these three market regions.

Net sales by market

SEK M	2011	2010
Europe	7,009	6,242
North America	7,541	7,200
South America	2,721	1,737
Asia	3,027	3,299
Other markets	1,991	2,038
Total	**22,289**	**20,516**

Deliveries by market

Number of buses	2011	2010
Europe	2,695	2,395
North America	3,014	2,092
South America	2,620	1,174
Asia	3,417	3,477
Other markets	1,040	1,091
Total	**12,786**	**10,229**

Figure 9: Volvo Buses Sales and Revenue (Volvo Group Annual Report 2011)

Figure 9 reveals an interesting fact. That is even though Volvo Buses is the second largest global producer of buses. The total volume lingers around 10000 units. If buses are produced in such a small volume it is difficult to justify the development resources and get the economies of scale.

5.4.1 Market Region Europe

Region Europe is divided into four sub regions north, west, south and central Europe. Originally being a European manufacturer Volvo Buses has a long history and significant presence in most countries of this region. This region is also one of the biggest contributors in terms of sales revenues. In Europe Volvo Buses offers the complete range of high end products in the city, intercity and coach segment. The coach sales are mostly retail, the city and intercity sales are tender based with varying quantities from 3-300 buses. There are three manufacturing locations, a chassis plant at Borås, a body/complete vehicle plant at Säffle and a complete vehicle plant at Wroclaw, Poland.

As this is the most mature market Volvo Buses operates in it has higher demands on product customization. During tendering process customers know exactly what they want and there is little chance of maneuvering the specification in favor of Volvo Buses. Some of the customers are even bigger than Volvo Buses and have a strong role in entire bidding process. The drivers are educated and experienced and are very specific about product details e.g. information displays, dashboard layout, drivers compartment etc.

This degree of customization also varies between different parts of Europe. In Nordic market the customizations are more geometric in nature i.e. Length, width, height of buses, wheel base etc. In the continental Europe there is standardization in terms of geometry but number of customization

requirements on seating layouts, driver's compartment, electrical equipment, AC/heating etc. One of the interviewees mentioned that due to the varying need for customization there is no standard bus in the Europe, every single order carries certain degree of customization. Even some of the big cities like Hamburg, Paris, Berlin require extensive city specific product customization.

The customization requirements are also depend upon the competition and the company's market share in respective sub regions e.g. In Nordic countries Volvo Buses has a strong presence, products are designed for Nordic market. Thus Volvo is overall trendsetter for product specification which means that there are comparatively lower customization requirements. But in case of continental Europe Mercedes Benz has the strong presence from last thirty years and thus it is an overall trend setter for product specification. So to be able to sell in this market Volvo Buses has to be flexible and take on customization orders which Mercedes Benz does not take.

To summarize, product customizations in this region are driven by mature and demanding customers, saturated and extremely competitive markets and continuous need to update the products to retain the market position.

5.4.2 Market Region Americas

The region Americas is the rapidly growing market region for Volvo Buses. It consists of North and South America and Canada and operates with three distinct brands, Volvo, Prevost and Nova bus. The products offered in this region vary from a simple, cheap city bus chassis to multimillion dollar motor home. It is a diverse region in terms of economy, population, operating conditions, weather etc. This triggers the diverse customization requirements in terms of product specification.

Starting from South America, in Brazil Volvo Buses is only into the chassis business for the heavy duty buses and works with the external body builders. There are some special customizations on chassis to have a seamless integration with external body builders. To compete with the local manufacturers, last year Volvo Buses entered into medium duty front mounted engine segment which requires completely different architecture. The chassis offering varies from simple city bus chassis to long distance double decker coach chassis with higher demands on the comfort and related features.

In Mexico where the complete bus manufacturing plant is situated Volvo Buses have market leadership in coach segment. It is also into city and intercity segment working with BRT truck line and corridors where the products range from 12 m low entry medium floor buses to articulate/ bi articulated low floor buses. An interesting situation with BRT system is the unique customization requirements influenced by political agenda, external advisers for BRT and limits of existing infrastructure. These orders quantities are large but PTAs are the major stakeholders and decision makers for product specification.

There is more for country specific customization. Rising oil prices is a common problem and a lot of movement is happening towards gas powered vehicles. Some of the countries in this region have the gas reserves and thus they promote its use in public vehicles. Due to the unusually high level of pollution, buses sold in Santiago have unique requirements on the filtration systems for AC's and Engines.

Further moving to North America and Canada Nova bus operates in the city bus segment producing complete buses. Prevost is in the high end seated coach segment but also in conversions i.e. using shell of a coach from Volvo Buses external companies turn it into luxury motorhome, special purpose vehicles for political parties, mobile command centers, and mobile hospitals etc. To cater to this unique customer segment, various interior and exterior customizations in chassis as well body are necessary.

On the driveline side which is the most impacting component in terms of customization, the countries in this region have emission requirements from Euro 0 to Euro V and US 10 to US 13. This demands for a broad set of customized driveline options. Making an over specified version as a standard is not possible as customers are not ready to pay for it.

Volvo has three distinct brands in Americas region separately dealing with development, component purchasing, manufacturing, testing and verification. To gain the economies of scale so far there is not much focus having synergies across the brands. Currently in the coach segment there is a co-existence of Prevost and Volvo brand in North America. The main problem in synergies is the distinct brand specific differentiating features. On the city bus side in theory products are very similar between Volvo and Nova bus. But here again, both the brands came from different backgrounds. They have different organizational structures. They have different brand heritage and do not share same credibility with certain features.

To summarize, the product customization in region Americas is driven by diverse regional variation between the customer requirements, legal and technical issues. This region could also benefit from commonality across brands but it is difficult due to the existing differences in the brands and organizations.

5.4.3 Market Region International

The region international is another new and growing market region for Volvo Buses. It is especially due to the rapid urbanization and developments in this region over the last decade. The diverse country specific customization requirements could be categorized in three categories.

High Requirements countries – These are the mature markets and very close to their European counterparts. Countries like Australia, Singapore, Hong Kong, South Africa have similar requirements

in terms of product features, emissions, performance, safety, comfort and customization as compared to Europe.

Medium requirements countries – These are the countries in South East Asia and Middle east that have a bit lower requirements in terms of customization. Volvo Buses can push the global products with some country specific small customizations.

Low Requirement countries - These are the developing countries specially India and China. Even if Volvo Buses sell the products only in top segment those quantities are still promising and rapidly growing. Volvo Buses sells complete buses in both coach and city commuter segment. Product requirements or specifications are driven by the company as these products are completely new in the market and Volvo is the market leader. E.g. In china there is just one single bus specification. In last 10 years it is only changed to cope up with emission norms.

The major challenge here is the local competition with the low cost products to get the higher market share in medium cost segment. Selling a global solution in these countries and segment is not a viable option because it would be over specified for market needs and customers will not be ready to pay for it. Second reason is these countries are not equipped to take care of service and reliability of high end technology e.g. Euro V Euro VI engines are not a viable option because there is no infrastructure for the urea mixing and troubleshooting of engine electronics.

To compete with low cost local competitors Volvo Buses has deployed an Asia leverage strategy. Through this Volvo Buses is developing a customized Asian brand of products by utilizing local development resources and supplier base. Basically Volvo Buses is downgrading the European product by removing high end features which are not required by the market, replacing costly components with localized parts and so on. But some interviewees mentioned that doing such changes in products are very difficult and time consuming because of the current complex integrated product architecture.

Till now the local competitors were focused only on domestic markets. Now they are developing products in India/ China that would also be sold in Europe or America. To compete with this kind of competition Volvo Buses also need to able to quickly upgrade the low cost products developed in Asia to fit in European requirements. This is the latest reverse trend being experienced by the company.

To summarize, the product customization in region international is driven by low cost product requirements in developing countries, strong local competition and diverse requirements in different countries. Volvo Buses also need to be able to upgrade and downgrade the product easily to target the specific markets and compete with the local manufacturers.

5.5 Dimensions of Product Customization at Volvo Buses

As described in previous chapters, due to the inherent customization culture in the bus industry, sales process with more say of the customers and the diverse conditions in the different countries, Volvo Buses has to provide the customized products for each order. Based on the information collected during this thesis, product customizations at Volvo Buses and their identified impacts could be grouped into three areas as shown in table 3.

Table 3: Summarizing Dimensions of Customization

Dimension	Customization	Identified Impact
Chassis and Driveline	Lengths, widths and wheelbases, floor heights (Low floor, Low entry, Medium, High floor) engines (Diesel, Hybrid, Electric, Gas), capacities (7,11,13 Lt), layout (Front or rear mounted engine),	Major structural and costly changes, Expensive development and maintenance, cascading effect on connected systems.
Body, Exteriors/Interiors	Lengths, widths, heights and wheelbases, door layout, seat layout, luggage racks, dashboard, drivers compartment, wheelchair support, toilets and pantries, windows, hatches, heating and ACs, Information displays	Additional development, Non standardized thus time consuming assembly process, Additional Verification and validation, Expensive aftermarket support
Cosmetic	Colors, fabrics, upholstery, ticketing machines, lighting, wireless routers, drop down screens, infotainment systems, software.	Quality issues , additional verification and validation, Expensive aftermarket support

The occurrence of these customizations varies depending upon the market and type of product. E.g. if only the chassis is being sold there will be more customization for integrating it with the body builders design. City/intercity product segment requires maximum customization in all of the three areas when compared to the coach segment. According to one of the interviewees city bus is a box with four wheels and everything else is customized. While in coach segment the customizations are on body, exteriors/interiors and thus more cosmetic in nature.

These dimensions of customization are further complicated by the constant need of product upgrades and without the option to take out the old product offering e.g. engine and drivelines are the most expensive parts of a bus in terms of development and maintenance throughout the product lifecycle. On top of that Volvo Buses needs to provide various fuel options which impact the overall architecture in different ways. More over Volvo Buses also need to maintain the engines with emission levels from euro 0 to euro VI because all these engines are still being used in various markets.

5.6 Product Customization and Need of Strategic Flexibility

The purpose of preceding investigation was to understand the common business and market drivers behind the customization needs in bus business and particular for Volvo Buses. At start of this thesis the author only knew that Volvo Buses need to customize the products for every order. To grasp its challenges and before suggesting any managing strategies it was felt necessary to understand the complete picture. The historical development in the overall bus industry reveals its fragmented, local, small scale past and the inherent customization culture in this industry. Even though the privatization and consolidation of business have started making the customers rethink about their customization requirements, the industry is still not mature enough to go for off the shelf offering. The sales process both in the tender and the retail business give very little room for the manufacturer to promote any standardized offering. So it is more or less clear that this customized-to-order phenomenon in bus industry is not going to change overnight. If a company aims to succeed in this environment it has to take customization as a business opportunity and find the ways to manage it efficiently.

It is particularly valid for Volvo Buses which use the customization as a selling point. For a long time Volvo Buses has been a European manufacturer selling bus chassis mostly in European market. Company was dealing with limited product offer and the complex, time consuming body building and customization part was handled by the local body builders. But now Volvo Buses is aiming to deliver a complete solution to its customers and that too in a much global and diverse market. The company is facing increasing competition both in mature and emerging markets by local manufacturers with cheaper products. On top of that, even if Volvo Buses is the second largest manufacturer of heavy buses it operates in a very niche segment and overall sales volumes are limited.

Summed up highlights of the background research are customization nature in this industry, global markets, diverse requirements, strong competition, dimensions of customization and the overall lower volumes. Given this background and as Volvo Buses aims to satisfy every customer requirement, it needs to offer a wide range of product variants. But higher the product variety company tries to embrace, greater is the complexity and also higher costs in complete value chain (Pasche, 2011). To minimize the negative effect of increased product variety, many companies have adopted modularization strategies. Modularization allows organizations to manage complex systems by decomposing them into smaller pieces with limited interdependence (Baldwin & Clark, 1997). Hence, modular design enables decoupling of components and systems, and creates an information structure that can provide embedded coordination, thereby providing the company with increased strategic flexibility (Sanchez & Mahoney, 1996). This background forms the basis for next part of the results where author undertook an investigation to identify challenges on core business processes and evaluate applicability of modularization strategies.

6. Results and Discussions Chapter II – Identified Challenges

This chapter of results and discussions explores the general views at Volvo Buses regarding product customization. It also identifies the challenges due to the customization requirements in the context of core business processes and related functions. A continues analysis and discussion helps to explore the applicability of the modularization strategies and its possible implications.

6.1 General View at Volvo Buses about Product Customization and Variety

The discussions in the interviews both formal and informal revealed many intriguing dimensions related to this issue. Interviewee unanimously agreed that enormous variety and questionable customizations is a common problem in the bus industry and specifically for Volvo Buses. For Volvo Buses customization is more of an embedded organizational culture. Usually it is used as a shortcut or quick fix. But many agreed that the important question is how long the company can afford it. Especially as this business operates on very marginal volume excessive customization has very serious effects on the bottom line of the business. In current global, extremely competitive and uncertain environment there is a pressing need to look at streamlining the product offer and to have more control over customization.

Another interesting finding was the way company reacts to the market demands. It is easy to presume that Volvo Buses would be the proactive market driver, as it is the second largest manufacturer of heavy buses. But in general, interviewees mentioned that Volvo Buses is most of the times reactive to the market changes. So the time pressure to deliver new developments is extremely high, which again leads to taking shortcuts in form of making customizations rather than going for a long term robust solution. Interviewees also mentioned that until now Volvo Buses tried to compete with every competitor in every market which is not a proper approach, company needs to focus.

Author also identified some conflicting views between marketing and manufacturing, product development about offered customization and variety. It is a classic dilemma. The internal functions i.e. product development and manufacturing had a general opinion that salesperson does not make much efforts to manage the customization requests. He just note down whatever customers ask for and just pushes orders down the chain. But marketing function has a view that having a broad variety or being able to customize to the individual customer needs is the business enabler. From marketing perspective, to get a tender or retail order company needs to have a comprehensive portfolio of products to match every customer requirement. But both of the groups agreed that there is a need of some sort of a golden way that could reduce the internal complexity and still efficiently provide the variety or customization. Given the background and general views, in the following sections the author tries to identify key challenges faced by different functions at Volvo Buses, while developing and delivering these customized products.

During the interview process the author followed the Volvo core business processes for better understanding and to get overall picture (Figure 10). The findings are also represented in the same way. In addition to the core business processes one section specifically focuses on the current organizational challenges on overall level. It is important to note that this analysis does not cover all of the sub processes; but only those which are thought to be relevant to the thesis topic are studied.

Figure 10: Volvo Buses Core Business Processes

6.2 Challenges due to Product Customization for Product Portfolio Development

Product portfolio development process works with planning and developing a comprehensive range of new products. The input for the process could be business plan, customer requirements etc. and output is verified and fully developed products & specifications. As part of this research, product planning and product development project management functions at Volvo Buses were investigated.

6.2.1 Product Planning

As mentioned in the general view, Volvo Buses is most of the time reactive to the market changes. It means that the product plans are driven by market situations rather than by company's vision. So during the last decade instead of product plan driving the products, the products were driving the product plan. The major drivers for the product plan were the changes in emission norms and the respective engine installation projects.

It is obvious that in absence of a comprehensive product plan it would be very difficult to coordinate the developments across the different regions. This has resulted in the number of products that overlap in terms of specifications but are still developed separately at different locations. E.g. a high specification product in India could be a medium specification product in South America or a lower specification product in Europe. In absence of clear product plan when a global product is to be modified for a specific countries it is difficult to comprehend how the developments should be carried out, so as to keep the products similar at both the locations.

Another problem with the product planning is management of product modification requests (PMR). A normal product lifecycle in bus business is 10-15 years. Thus usually a product requires periodic facelifts and introduction of the new variants throughout its lifecycle. So if there is no clarity about how the product is going to evolve during its lifetime the current development does not support the future changes. It has resulted expansion of product variety and complexity.

Recently there are some efforts being done to address this issue. Volvo Buses have established a range management team to develop a portfolio of products and projects by making and following a global product plan. By this company is aiming to proactively develop the products considering all future demands and only make the small customizations wherever necessary. To come up with such comprehensive product plan different channels of inputs such as customer surveys, competitive benchmarking, legislation studies, technology trends, Volvo group core values and company strategy are planned to be explored. Company is also trying to come up with technology and feature roadmaps for future products. Based on above inputs, so far total 8 level 1 product features are identified e.g. comfort, fuel efficiency etc. those could be broken down into 44 level 2 sub-features and 180 level-3 sub-sub features. There are approximately 37 physical systems in a bus that could influence these features or vice versa.

The main problem with execution of this strategy is mismatch between the product features, physical systems and supporting development organization. The complex interdependencies require much more coordination to actually follow this roadmap. In terms of development organization even though there is an upstream organization in form of range management team the downstream organization which would actually operationalize these strategies is missing. The downstream organization would require feature leaders and cross functional teams working on a particular feature.

6.2.2 Product Development Projects

As explained in the company background there are mainly two types of product development projects at Volvo Buses requiring different amount of activities, scope, and budget, resource requirements. Those are called ‘start cost projects’ and ‘maintenance projects’. The start cost projects are major projects resulting in the new products or extensive modification of the existing products to fulfill legislation needs. The second type is the maintenance projects also known as product modification requests (PMR). They deal with small maintenance of existing products aimed for quality improvements, cost rationalizations or specific customizations.

Author made an important observation was made during the interviews regarding the scope management of start cost projects and its implications on product customizations. Normally before starting any new development projects the pre requisites are collected from different stakeholders. Those prerequisites form a list of product/feature requirements that are supposed to be delivered by the project. Volvo Buses always struggles with limited budget and resources which requires reduction in project scope. Thus some of the original requirements are not completely fulfilled by the project. But as customers still need those demands fulfilled they come back again in form of customizations in an order. This result in lot of unplanned rework on already developed product and increase in complexity. Even though there are limited opportunities to deal with budget or resource constraints, there is still a possibility to anticipate future changes and develop products that are easy to change. Some of the

interviewees agreed that it would be much better if development projects could modify one part of the product without affecting others. That needs a modular decoupled structure with clear interfaces.

To make an informative decision about scope reduction by anticipating future requirements it is necessary to have well written pre requisites/ requirements for the project. That means the front loading the development process. Many interviewees mentioned that it is very hard to make people give detailed inputs for these projects. Most of them are busy in firefighting and handling current issues. It is same with the project managers as their performance is connected to delivering that project on time and not to deliver a product that would be easy to change in the future. The customer adaptations department handles day to day product customization and their input could help a lot of customizations to already include in the project. But today it is a different entity and it does not have a larger say in the early stages of product development.

During product development projects, attention is given to costs associated with development of new parts and cost of new components. But there are also lots of internal costs that are carried in the system but not given attention. E.g. cost of documentation, product system up gradation, aftermarket readiness etc. so in the end each component carries large amount of internal costs. Interviewees mentioned that sometimes in the product development projects there is no proper attention is given to retain the old parts. In some cases existing parts are deleted before payoff and it indirectly affects the budget.

Now if we analyze the challenges in product portfolio development the first interpretation could be drawn from company's historical development. As mentioned before, for most of the time Volvo Buses was selling only chassis and thus had limited complexities in product development projects. The more complex and time consuming customizations usually happen on body side and were handled by external body builders. Even when Volvo Buses acquired different body building companies, the strategy was more or less just to maintain the old bodies/designs and make only incremental changes. But now as the company is trying to plan and develop complete new products the old ways of working are no longer suitable.

The challenge with product planning is to streamline the global products and effective coordination of product upgrades throughout the product lifecycle. Now if we go back to the theories of modularization, it offers company a strategic flexibility because of well-defined interfaces. Different modules could be interchanged without heavily affecting the environment (Baldwin & Clark, 1997). This could be beneficial for Volvo Buses because it requires constant upgrades of products. Volvo Buses could also use modularization strategy to localize the variation to only single module. In that way most of the modules could be reused even between the regions, helping streamline the global products. The work that company is doing with feature roadmap is in right direction. But as mentioned before the connection between the features, physical systems and organization is missing. This could be overcome by designing the modules that have one to one mapping to the feature requirements and

rearranging the development organization mirroring the modular structure. Detailed interface designs in advance resolve potential conflicts between the involved development organizations (Shamsuzzoha, 2011).

In case of product development projects, managing the scope of the project due to budget and resource restrictions, getting inputs for prerequisites and reuse of old components and systems are the key issues. If Volvo Buses adopts modularization where modules could be designed and updated independently, then actually company does not need to work with large projects. That could be done by series of mini launches by modifying one module at a time. Modularization could also address the issue of getting inputs for prerequisites in two ways. First of all if we refer to product development process for modularization puts a lot of focus on system level design (Ulrich K. , 1995). Thus this dedicated phase could facilitate gathering of all the requirements early on. Secondly as the scope of every mini launch is limited, each module could be optimized perfectly. As the modularization creates lose coupling between modules and most of the modules could be carried over in successive mini launches it could increase the reuse. Thus direct/indirect cost of introducing new components could be significantly reduced.

6.3 Challenges due to Product Customization for Sales-to-Order Process

During the sales to order process the right product is identified as per customer needs and product specifications are negotiated to finalize an order. In the tender process company sends a bid/quotation and in retail business salesperson directly interacts with the customer. As this process is the first link between the company and its customers, it has a significant role in relation to product customization requirements.

During the interviews many participants emphasized that, the lack of initiative from the sales person to sale a standard product could be the main reason behind frequent product customizations. According to them sales process today is more of an order taking process. There is no standard specification for any product, just a tentative offer that could be customized as per the customer's wishes. There is actually a lot of scope to steer the customer to go for a standard solution. To check the validity of this hypothesis the same question was asked to the participants from product marketing. They presented the other side of the coin.

Referring back to the historical developments in bus business, the customers are very prone to go for a special customized solution for their own operations. That mindset of the business is built over decades and not very easy to change. So during the sales to order process it is difficult to have a customer dialogue with very limited offer. Take it or leave it strategy will neither work with bigger, stronger customers nor with small customers who buys from heart. It is especially not good for Volvo Buses because being able to deliver customized products is the main selling point in many competitive

markets. In some cases the sales person himself could get confused due to large number of overlapping product offers. It is also very difficult to understand and explain the cost implications of specific customizations to a customer.

Another challenge for this process is the limited time between getting a final order and delivery dates during the tender process. If a tender specification requires a lot of customization that need to be developed from scratch, the development has to be started even before getting an order. It involves various activities, needs resources and incurs costs. From a general estimate there is only one in three chances to get a tender. Sometimes more customization requests creeps in even after the order is finalized. This required faster ability to make the changes in existing products.

After analyzing different viewpoints about the sales to order process it is clear that there is need to understand how the customization requests should be handled during this process. On one hand company cannot go for just one standard offering and the other hand it cannot accept excessive customization. An intermediate strategy needs to partially customize to individual needs based on a standard set of modules could be useful (Ramdas, 2003). The mix and match flexibility of modular product architecture may be used to increase number of product variations offered in this process (Sanchez R. , 1999) (Muffatto & Roveda, 2002). But before doing that it is important to decide how much customization should be offered. The current work being done at Volvo Buses in terms of feature roadmaps could be used to understand what customization customer values the most. Then the modules or components could be designed to provide an array of choices. So in this way company can steer the negotiations based upon what customer values the most and keep most part of the product stable.

This way the confusion of salesperson about the product offer could also be reduced. He could make a well informed decision about what to promote and what not to promote. He could further be motivated by an incentive scheme for promoting the only available choices. He can also be aided by advanced cost calculators to put down exact lifecycle cost of each customization in front of customer. In the end every customer in this business now cares about the lifecycle cost of the product he is buying. By using the predefined, predesigned standard modules time to market could be significantly reduced. The development activities for an order could be confined to only some small last minutes changes. Marketers might argue that by using this approach company will lose some of the orders. In case of these complex expensive products, increased modularization can attract new customers by improved price/performance ratio, better quality and time of delivery (Hvam, 2008). In the long run it could help expand into specific markets by offering the customization only on features that are actually valued by the customers.

6.4 Challenges due to Product Customization for Order-to-Delivery Process

Order to delivery process at Volvo Buses includes all the activities after receiving an order to finally delivering the buses to the customers. The activities focused in this section of result are customer adaptation process, which is used to modify product as per customer order, sourcing and supply of customized parts/assemblies and finally manufacturing the buses in the factory. One of the main challenges discussed during the interviews was the limited delivery time which is usually 3 to 4 weeks. Thus increase in product customization has direct implications on this process.

6.4.1 Customer Adaptations Process

When an order requires some changes in existing product specification, Volvo Buses utilize a very fast and less formal process for adapting products to the customer needs. These are mainly small and medium changes required on the product. Normally this process begins before company bids for a tender. The existing product specification is compared with the required customer specification and some parts are added and deleted from the bill of materials. The cost for the new parts is calculated and checks for the feasibility are done for taking or not taking the order. Parts which are added are either developed for the order or reused from the old order. There is no formal documentation for customer adaptation components or subassemblies in the product data management (PDM) System. All the adaptations are handled by a separate customer adaptations (CA) department located at each manufacturing location. They directly interact with marketing and normally report to the manufacturing function but recently a dotted line reporting to local product development function is being established.

During the customer adaptations process an important issue is to put all pieces of order together, so that company can decide on most fitting product offer. Because the more the product is matching with the order specification the less customization would be required. It is especially valid for tender business. In the tender process with multiple stakeholders, due to late communication between Public Transport Authorities and private operators, a lot of last minute changes are requested. As these changes are not anticipated when deciding initial product offer in the bid, it adds up more customization.

When asked about how easily the existing products could be customized, many of the interviewees mentioned that the existing product structure does not allow easy interchanging of parts. The problem is a single component is attached to the different classes of material/variants at different levels. Thus removing one component altogether affects different systems. The product is not designed or documented in a modular fashion which would allow easy interchange with standard interfaces.

Some of the interviewees mentioned that, at Volvo Buses customer adaptations are used to cover up all other problems. Sometimes these are wrongly used to address a quality issue. Some of the customer

adaptations are supposed to be one time quick fix for a particular order and not a long term solution. It is not properly documented and design is not optimized or verified. So if it is occurring repeatedly it should be carefully developed and included in standard product offering. But most of the time, once an initial order is served by a customer adaptation it is just used again and again for other orders. It would cost less and increase the quality if frequently occurring customizations are carefully integrated into future product development. That feedback loop is currently not in place.

6.4.2 Component Sourcing

Sourcing or purchasing function at Volvo Buses is responsible for timely supply of regular components and as well as specific customer adaptation components to the assembly line. It involves various activities such as supplier identification, price negotiation and quality assurance. Main challenge here is due to the overall lower volumes at Volvo Buses. Because of the customizations and lack of commonalty between different product families many components are unique for specific market, product combination. In many cases for same function there are different part numbers. A general trend is increase in number of unique components at all the manufacturing locations. These components carry both direct and indirect costs to the company. Due to the small volume it is difficult to get a supplier and negotiate the prices. In case of customer adaptation components there is only limited amount of lead time. These customer adaptation components are normally for one order so finding a supplier, insuring proper quality in that limited time is very tricky. In some cases company needs to buy more than necessary to fulfill economic lot sizes of the supplier.

6.4.3 Manufacturing Planning and Final Assembly

Manufacturing of highly customized products is a challenging task. It requires more flexible manufacturing process. Because first of all due to variation in product customization requirements, standard working time differs for every order, so line balancing on the production line is a challenge. Secondly due to previously discussed complexities in component sourcing, timely availability of customer adaptation components is tricky and this might result in line stoppage or rework. Third problem is assuring the quality of customization work. Except bigger customizations most of the customizations are put directly on the line without proper testing and verification.

Typically a two axle bus takes around 1200 man hours to manufacture and it is very labor intensive work. Normally 30% of assembly is done offline and 70% online, this setup is quite time consuming and costly to manage**.** Volvo Buses is running a project for many years named B50 to cut the production time of buses in half. Now to reduce the assembly time and make the process lean, most of the assembly work should be carried out offline in form of modules. Those modules should be tested and verified independently and then directly put together during the final assembly. This strategy is only possible if the product is designed keeping production modularity in mind, which is not a case today.

Now, looking at the challenges for order to delivery process, couple of strategies could be discussed. The problem with the customer adaptations is the complex integral nature of current products, both physically and in documentation. Changes to the product are most easily accommodated through modular architectures. It localizes changes that are typically associated with a product functions to the minimum possible number of components (Ulrich K. , 1995). Fully specified component interfaces allow effective component level learning process. This decoupling could also allow participation of suppliers and customers in localized learning in developing specific modules (Sanchez & Mahoney, 1996). But it means that the company needs to invest a lot to understand the customer's desires about the product. Only then the modules and the interface specifications could be carefully designed to maximize customer value. In case of Volvo Buses the customer adaptation function could give many valuable insights in the early stages of this development. Current problem with this feedback system is time restriction and more pressing day to day priorities. If these inputs could be focused to develop one module at a time it would be more practical for getting inputs. Utilizing this information, company can proactively plan for a large variety of products while mixing and matching less number of components. It could also address the uncertainties and last minute changes in the bidding process.

Component sourcing at Volvo Buses struggles to achieve economies of scale due to the lower production volumes. Every new part adds direct and indirect cost to the company's operations. It would be beneficial to have maximum component commonality and reuse. Component commonality can arise only when (1) a component implements commonly useful functions (2) the interface to a component is identical across more than one different product (Ulrich K. , 1995). Both of these conditions could be met by implementing modularization strategies. It supports one-to-one mapping between component and function, plus it standardizes interfaces across range of products. The increased volumes per component/assembly could also allow complete outsourcing to the supplier. Normally a standard component is less expensive than a customized component. But in some cases using a standardized component from a higher product range in a lower product range will make the product over specified and expensive. The customer for the lower product range might not be ready to pay for this additional cost so company has to bear it. It could still be justified by economic savings from reduced complexity in sourcing, inventory management, quality control and aftermarket support.

Developing higher product variety triggers high complexity over production line and therefore need to be efficiently managed (Scavarda, 2010). Modularization could decompose problems into sub-problems, thus reducing complexity, time and resource consumption (Shamsuzzoha, 2011). Modularization could allow more offline production and pre-assembled, tested and verified modules could be fitted directly on main assembly line. In that way it will reduce the issues in line balancing and allow more efficient utilization of resources. The main challenge for Volvo Buses is to have similar manufacturing processes at every manufacturing location. Manufacturing sites worldwide

depend upon key subassemblies which are supplied by factories in Sweden. Unless they have similar manufacturing processes it is difficult to keep everything streamlined. It could be a bit tricky because the different countries have varying labor cost e.g. cost of producing a body in India is less than half of cost in Sweden.

6.5 Challenges due to Product Customization for Delivery-to-Repurchase Process

Core business processes does not end after delivering the product to the customer. Actually it is just a start of a long term relationship with the customer until his next purchase. The sold buses are in operation for almost 15 to 20 years and thus require regular aftermarket support. Aftermarket business is a major revenue generator for Volvo Buses. Some of the interviewees even mentioned that Volvo Buses hardly get any money out of selling buses, it is the 130,000 Buses on road that generate constant revenue irrespective of changes in business cycles. As the Volvo Buses is aiming to be a complete transport solution provider, it offers lifetime service contracts and operates an extensive spare parts business. Volvo Buses is committed to support the customer with the aftermarket services and spare parts till 15 years after a bus has been sold. Now as the overall bus business is showing interest in Life Cycle Cost, higher product reliability, easy maintainability and lower service turnaround time are of more importance in the purchasing decisions.

As mentioned before in order to delivery process, small customizations made for specific order are not documented in PDM system or in standard bill of materials. In that case a service person cannot find that part into standard service manual/part catalogue. Some of the customization components are manufactured just for one order so company may not have it stored in the inventory. So it takes a longer time to identify and get the spare parts for such customizations.

Another problem is due to the regular product upgrades. A bus or chassis product lifecycle is 10 to 15 years and regular facelifts are planned to change the product as per evolving needs. But as Volvo Buses is not following standard interface designs the facelifts considerably change the product architecture over the years. But a customer might need to replace major product sections in case of an accident. Buses are usually sold multiple times throughout its lifetime, so a new owner who bought buses on resale may want to make some major changes. In that case company needs to maintain both old and new designs in the systems, which is very costly due to increased number of parts. Even if customer prefers to upgrade his old product with the new facelift, it will take a lot of handy work and adjustments to fit old with new.

Based on above observation it is evident that the complexities due to product customizations have implications even after the product is sold to the customer. Customers usually associate Volvo brand with higher product reliability. To maintain this perception is getting more and more challenging due to increased complexities in product offerings and customizations. On the other hand, as customers are

getting more aware about the Life Cycle Cost, now Volvo Buses can use this as a good tool to make a business case to sell more standard product and negotiate product customization demands.

The architecture of a product is closely linked to the ease with which a change to a product can be implemented during its lifetime (Ulrich K. , 1995). Modularization helps to improve the reliability and maintainability of the product because of standardized modules and increased module level learning (Sanchez R. , 1999) (Shamsuzzoha, 2011).Modularization could also help in reducing variety of replacement parts in inventory and service staff training requirements (Sanchez R. , 1999).Most of the city bus customers have their own workshops and they appreciate having commonality between different vehicles. It helps them to carry lower spare parts inventory and less training needs for the technicians. It also applies to service centers operated by Volvo Buses for small to medium sized customers.

Lego pieces made in 1963 still interlock with pieces made today; it is only possible because of modular designs and standardized interfaces that are kept constant throughout all these years. It could also apply to Volvo Buses. In modularized product, modules are easily upgradable without requiring extensive changes to the other parts of the product (Baldwin & Clark, 1997). On the other hand more focus on keeping the interfaces stable will reduce the chances of architectural innovation. But that risk would still be marginal as bus is a very conventional product with slow speed of architectural changes.

6.6 Organizational Challenges

Developing complex, customized products requires organizational flexibility, effective coordination between different functions and faster decision making processes. This section of results analyzes different organizational challenges being faced by Volvo Buses on overall level.

If we look at the Volvo Buses history, traditionally Volvo Buses had a very strong headquarters in terms of experience or expertise in developing buses. The hubs/sites in different countries were mainly working with country specific small customer adaptations. So flow of information or decision making authority was from the headquarters to the sites. But now the global market scenario for Volvo Buses is changing. European market is getting saturated and major growth is happening in Asia and South America. Strategy of just adapting European product to local need is no longer sufficient and special products for these markets are being developed. It is not viable to design products in Sweden for selling in developing markets e.g. India. Because labor cost is Sweden is more than five times than in India. Thus company is planning to expand the global development presence by a global foot print. It would bring improved knowledge of local conditions and increased speed and reduced cost of development. In this situation, a highly centralized decision making structure would not be appropriate. Some of the interviews mentioned that even though Volvo Buses is a small organization, due to the complex, overlapping roles and responsibilities the proper communication on decisions is

hard and time consuming. Especially when there are changes of cross functional nature required on global level, somebody actually has to push it through all the organization. To gain the advantages from global footprint a decentralized decision making process is necessary.

Today many companies are utilizing their global development resources for developing new products at much faster and cheaper level. These distributed resources work both for developing local and global projects in a completely virtual environment. Volvo Buses is comparatively new to this approach and from a general opinion; it is not working very well. Especially in collaborative development breaking down the work across sites and coordinate parallel global development are the main challenges. E.g. to utilize the global footprint PD hub in India should support product development globally by owning and developing specific work packages, but today breaking down the product into self-contained work packages is bit tricky. Thus delivering this work packages requires a lot of coordination, meetings and conflicts management due to complex interdependencies between different product systems.

Another typical organizational issue observed at Volvo Buses is management of knowledge. As discussed in the customer adaptations process, documentation of customizations is less formalized. The connection between the product plan and regular product upgrades is hazy. In this case, to develop new products considering past and current developments, the people involved must have a deep architectural understanding about the complete product over its lifecycle. But because of the small size and to cope with business uncertainties Volvo Buses generally works with many external consultants. Consultants come, they work for some time and leave with the product/process knowledge. It results in unnecessary redevelopments and inventing the wheel again and again.

To summarize the finding of this section, the main organizational challenges for Volvo Buses are, decentralizing decision making process, coordination of globally dispersed product development, and retaining the knowledge and learning's about the products. Now if we look at the previous researches, organizations which are developing products often organize product development processes mirroring the architecture of product they develop (Henderson & Clark, 1990). Or in other words products design organizations (Sanchez & Mahoney, 1996). So if we look at the case of Volvo Buses, the complexity in the organization today could be connected to the complexity in the product architecture. More simplified the product, more simplified organization. To meet this challenge (Garud & Kumaraswamy, 1995) suggests designing 'modularly upgradable' organization systems which will allow constituent members to work independently and in unison, while evolving with time.

By applying modular product architecture Volvo Buses can achieve this modular upgradable organization system. Modularization defines the interfaces and makes modules as decoupled as possible. In that case development processes could also become loosely coupled as the modular

product architecture with its standardized interfaces creates an information structure that enables embedded coordination (Sanchez & Mahoney, 1996). If the module boundaries are drawn around activities and processes where coordination needs are more intense, it could minimize need of coordination between module teams. The decisions on the module level could be taken locally without raising concerns up the hierarchy as long as the interfaces are kept constant.

Modularity increases the ease with which system designers can substitute certain system components while retaining all others (Garud & Kumaraswamy, 1995). This upgradability provides designers with the opportunity to work on an already established technological base thereby preserving their core knowledge base (Wheelwright & Clark, 1992). So for Volvo Buses even if there is higher turnover of external consultants, the stable modular structure would act as a technological base for preserving knowledge. Modularization also creates loosely coupled knowledge domains focused on each loosely coupled component or module. Thus by reducing the complexity of interaction between different modules, modularization may lead to greater speed and efficiency in technological learning.

6.7 Summary of Challenges and Applicability of Modularization Strategies

Table 4 summarizes the challenges for core business processes due to product customizations and applicability of modularization strategies to address these challenges. Based on these summarized findings author could conclude that the modularization strategies if properly applied have a potential to address most of the challenges faced by Volvo Buses core business processes and organization.

Table 4: Summarizing challenges and applicability of Modularization strategies

Core Business Process	Challenges due to Product Customization	Appicability of Modularization Strategies
Product Portfolio Development	Stream-lining global product offering and effective coordination of product upgrades throughout the product lifecycle.	Due to the strategic flexibility offered by well-defined interfaces different modules could be interchanged or modified without heavily affecting the surroundings.
	Missing connection between features, physical systems and development organization.	Modules could be designed to have one to one mapping with product features. Modularization of product also provides a framework for modifying the organization. At the same time clear interface designs resolve potential conflicts between the involved development organizations in advance.

Core Business Process	Challenges due to Product Customization	Appicability of Modularization Strategies
	Reduction in scope of the projects due to budget and resource restrictions, resulting in subsequent requests for customization and getting correct inputs for setting prerequisites..	As the modules could be designed and updated independently it reduce the need of planning bigger projects at one time. Instead development could be carried out in series of mini projects per module. It also makes it convenient for people to give inputs for setting project prerequisites.
	Increasing reuse of old components and systems.	Due to the lose coupling between modules most of the modules could be carried over in successive mini launches facilitating reuse.
Sales to Order	Confusion due to large number of overlapping product offers.	With help of predefined modules the overlap between product offers could be reduced.
	Limited time between winning the tender and delivery date. Only one in three chance of winning a tender, risk of losing investment in development efforts.	Properly designed predefined modules could be mixed and matched as per the tender requirements, reducing the need of new development for every tender.
Order to Delivery	Changing the existing products in PDM system. Different views of CA and PD organization on product documentation.	If product is developed and documented in modular way it facilitates easy interchanging of components and systems.
	Many unique components in very small quantity making it difficult to find a quality supplier and negotiate prices.	Modularization promotes reuse of components and systems across range of products due to standard interfaces thus increasing economies of scale.
	Complexity and increased need for flexibility in manufacturing. Line balancing and resource constraints.	Modularization decomposes the product which makes it possible to do most of the subassembly and testing/verification offline and directly put together in final assembly reducing tact time and resource consumption.

Core Business Process	Challenges due to Product Customization	Appicability of Modularization Strategies
Delivery to Repurchase	Longer lead time to identify and supply customized spare parts as today they are not properly documented. Time consuming Nonstandard service instruction.	Modularization helps to improve the reliability and maintainability of the product because of standardized components and increased module level learning.
	Regular product updates deviates the products making it essential to maintain both old and new designs for ensuring customer support.	Standard interfaces make it possible to modify one part of the product without affecting rest of it. Thus in case of replacing modules old can fit with new if interfaces are kept constant.
	Need to carry inventory of all the unique parts to support customer for 15 years.	Modularization reduces number of unique parts by facilitating reuse.
Organizational Challenges	Expanding global footprint and decentralizing decision making.	Decisions on module level could be taken locally without raising concerns up the hierarchy as long as the interfaces are kept constant.
	Breaking down the work across sites and coordinate parallel global development.	Modularization can design 'modularly upgradable' organization systems which will allow constituent members to work independently and in unison. Standardized interfaces create an information structure that enables embedded coordination.
	Management of knowledge and learning irrespective of high resource turnover.	Easy upgradability provides designers with the opportunity to work on an already established technological base thereby preserving company's core knowledge base.

7. Results and Discussions Chapter III – Past and Current Efforts

After analysis of the challenges due to product customization on different core business processes, this chapter of results assess the progress of previous efforts done by Volvo Buses to address these challenges. These efforts were done on both the ends, i.e. externally to reduce the customization by streamlining the product offer upfront and internally by incorporating modularization approaches during the development of the new products.

7.1 External Efforts – Streamlining the Product Offering

For several years Volvo Buses is working with the different players in bus industry, public authorities and private transport companies to standardize product specification. In late 90s Volvo Buses started a project called norm bus 2000, a standardized specification of buses for a group of public transport authorities. A year ago norm bus 2010 also came into picture. Volvo Buses is also trying to implement pilot studies to track the customer purchasing behavior by recording information from regular visits, questionnaires, and other sources so as to have detailed inputs for new development projects. This is complementing the feature roadmaps discussed before which are being incorporated in product planning. The aim is to proactively understanding customer needs and preferences and offering a product accordingly.

An important challenge for companies developing large variety of customized products is controlling the variety and cutting down the tail. There are always some products that are sold only once or twice a year in limited quantities. If they require unique customized components then direct and indirect cost to maintain those variants cannot be justified. But to decide on taking away these product offers means losing out that specific customer, which makes the decision making process more challenging. Volvo Buses also faced the same problem, especially when Volvo Buses acquired a Finnish body building company the combined product portfolio has 50 different combinations of lengths and heights. After a study it was concluded that only 3 lengths and 3 heights with 9 combinations are mostly used and loss of volume for other combinations is negligible. Also in case of driveline combinations i.e. different engine sizes, installations, ratings, gearboxes, rear axles there were more than 900 combinations, some of them were never sold. After analysis it was concluded that only 300 of those combinations contribute to 70% of the sales. Then the large numbers of combinations were taken away.¨

As Volvo Buses is part of Volvo group, being associated with the larger truck brand provides multiple opportunities to harmonize and gain economies of scale. Power train is an expensive and complex piece of system in a bus. Volvo Buses use the same truck power train as it is and only makes some small software changes to make it suitable for bus operations. Product plans for power train technology are thus strongly connected to truck brand. Other than sharing the components or systems, Volvo Buses also share service centers, spare parts business and dealer network with truck brand.

Problems for such kind of rationalization are different product requirements in different regions, markets and different launch timings for new products. E.g. buses with Euro VI engines are being developed to cater the legislation coming in force from 2014 in the European market. On the other hand Euro VI is not on map of either Americas or International markets and it might come up in 2018. So until then the company has to maintain all the different old combinations.

Another thing is the way these efforts are managed. Most of the times it is a quick reaction by one of the departments when they notice increased part numbers in design or manufacturing. A project is undertaken to reduce unique part numbers by communization or cost rationalization. But the implications of such changes on overall business are missed. So eventually these changes are forgotten and situation comes back to where it was before or even worse. A constant monitoring or control mechanism is missing at Volvo Buses.

7.2 Internal Efforts – Modularization Strategies in New Product Developments

Volvo Buses is not new to the modularization strategies. Few years back there was a pre-study undertaken by advanced engineering-product development function to formalize modularization strategy at Volvo Buses. A lot of work was done during that project in term of conceptualizing modular vision for Volvo Buses, defining key modules and interfaces and future action plans for making these changes. But even after all this work the suggestions did not realize in practice. Some of the interviewees revealed the reasons behind that.

- First of all it was a stand-alone project initiated by product development; the other important stakeholders like marketing, manufacturing were not part of the pre-studies. These strategies have implications for the whole organization and thus require a drive from senior management and involvement of all the stakeholders.
- Secondly, the project worked in detail on defining modules, possible commonalities, and interface designs and so on, but the organization structure which should carry out and coordinate these activities in day to day operations was missing. Changing the way of working without properly defining roles and responsibilities was not possible.
- Last but not the least; Volvo Buses has a relatively small business and restricted budgets, so it cannot afford to run standalone process development efforts, those efforts needs be connected to an actual development project. But this standalone pre-study was not connected to actual development project. So in short lessons learnt from this project were more of theoretical nature and have been kept in a cold storage since then.

But in recent years, the business scenario for Volvo Buses is rapidly changing. New growth regions are identified in emerging economies in Asia and South America. These regions have different requirements on products than their European counter parts and the strategy of adapting European

product to these countries is no longer a feasible idea. Over the years these adaptation have made existing products very complex, demanding a complete design overhaul. Also the existing products are aging and new, fresh products are needed to retain the premium brand image in the market. So now for the first time Volvo Buses is undertaking new product development projects for global products. This was perceived to be a good opportunity to incorporate the learning from the previous modularization project and included into the project pre requisites. One of these projects was studied with special interest to explore how these strategies are working out during the new product development projects.

Project X

Project X is a first of a kind development project for Volvo Buses where a completely new product is being developed for global markets. As explained before the product being developed in this project is for global markets. The development work is being carried out globally with specific sites responsible for developing different systems and variants of the products. An extensive pre study was undertaken to gather the requirements of different markets beforehand to reduce the future customizations. Newly formed range management team put a lot of focus for planning the commonality across the variants and different classes of products. By taking inputs from the previous modularization project different modules are defined on a higher level e.g. front module, rear module, roof module etc. This was done by taking all the stakeholders into consideration e.g. marketing, manufacturing. The requirements specification also contained some requirements dedicated for interface designs. So on paper it all looked very well planned. But during the observations of project meetings, documentation or milestones it was found out that these strategies are actually not working. Discussions with the Chief Project Manager and other managers associated with this project revealed a realistic picture about implementation of modularization strategies.

- In the initial stages of the project there was a lot of confusion between the project team members regarding what exactly modularization means in context of Volvo Buses. The knowledge was more or less of a theoretical nature. Many people were actually under impression that the platform is a chassis. Some of the senior members of the project worked before with Volvo trucks and were aware of their platform and modularization strategies. But the bus business is different from the truck business. Especially looking at the higher degrees of customizations, lower volumes, small development organization and traditional company culture, trying to implement these strategies as it is was not a good idea.

- This project is a first project where completely new product is being developed. The development organization at Volvo Buses has always been working with product maintenance, which has something solid to work upon. So working on fuzzy front end and coming up with new concepts was a challenge for developers. Modularization requires much work to be done on system level design which demands for a deep architectural knowledge about the product. Many project

members did not knew how to do it, how much time it will take, whom to coordinate with and thus most of the work ended in a loop. Many of the interviewees mentioned that learning and implementing these new strategies while working on tight budget and timelines was almost impossible.

- Transferring the modularization strategies and ideas to actual workable level requires an effective organization and clear roles and responsibilities, which was not planned in this project. There were module leaders appointed within *Global Engineering* but modularization requires a cross functional team giving inputs from each of the perspective e.g. manufacturing, marketing, purchasing. Thus only establishing module responsible was not enough. It would further require organization for managing modularization process, coordinating between modules; design the interfaces and so on. In absence of such an organization lot of conflicts were created between line and project organization. People started doubting if these strategies ever work at Volvo Buses. Many of these ideas were skipped because of the time pressure and budget restrictions.

- Another problem was with the coordination of global development. Modularization allows breaking down of task complexity and makes modules loosely coupled. It also creates an information structure which reduces the need of coordination. But in this case as developing modules was part of the project it was a catch 22 situation. This is kind of a vicious circle company got stuck in. Because of complex inter linkage in products; a lot of coordination was required for success of virtual global working. If one site is developing a part of product to be used in another country, lack of knowledge about local needs created many conflicts e.g. development team in Mexico were not fully able to understand need of European market while developing wheelchair solution. Many interviewees said if all the development organization was seating in one building lot of coordination trouble would have been saved.

Finally because of all these reasons it could be concluded that modularization strategies do not seem to be working in this project. The project ran out of budget and missed important deadlines. So now the company is the firefighting mode. Some actions were taken to bring all the development teams from different sites together in Göteborg to improve the development effectiveness. The scope will be reduced which will make this project just another facelift rather than a completely new product. It is a big setback for modularization strategies because this kind of project decides the product offering for next decade and if something has to be changed it has to be now. Otherwise it will be years before such new project will come by.

To summarize the efforts done so far, company tried to work on both external and internal fronts by applying different strategies to manage the customization. But it is struggling with the implementation. In the subsequent chapters author will try to give recommendations to address the implementation issues.

8. General Discussion

This chapter is aimed to discuss the general reflections of the author regarding the overall thesis methodology and the thesis results.

8.1 Thesis Methodology

In the start of this thesis the author had very limited knowledge about the Volvo Buses. It was clear from the problem description that this thesis would need to encompass whole spectrum including business overview, markets, customers, products, processes and organization. So it was necessary to apply an exploratory approach to gather the information from different perspectives and connecting the dots together. Interview guide designed based upon the initial informal discussions and secondary research was proved to be a good tool to gather this kind of information. It was also used as a framework to analyze and connect the bits of information together. The main success point in utilizing the interview methodology was the active participation of experienced managers and the real life experiences they shared. Semi-structured layout of the interview guide allowed both the author and the participants to follow a particular idea in much more detail.

The major challenge in this thesis was not how to get the right information but how to process it and present it in an intuitive manner. Initially the author tried to find the red thread through the gathered data to construct a connected story, but somehow it was not very easy to follow. It was mainly due to the different angles within gathered information. So instead of presenting the results and analysis together the author decided to break it in three parts separately addressing different thesis objectives.

In the retrospect, it could have been a better idea to limit the scope of this thesis. In that sense the author could have given justice to one particular area. But in the quest of getting the whole picture the scope of the thesis kept expanding. Due to the large scope of the thesis only explorative part could be completed. Even though the author tried to confirm some of the findings, a cross functional workshop or a field study of customers/sales process would have given even better confirmation.

8.2 Thesis Results

As discussed in the methodology the results and analysis part of this thesis is divided in three distinct parts. Each part addresses particular set of research objectives. For easy reading and better understanding each of these results are combined with analysis and discussions and already presented in previous sections.

Results and Discussions I provide an overall view of the bus industry, evolution of this industry so far, nature of sales process and overall customization culture in the industry. It was evident through these findings that the customization culture within the customers and manufacturers is deeply embedded over many decades. Even in today's era of privatization and demand for cost effective solutions this industry is not ready for completely off the shelf standardized product offering. The typical sales

process associated with buses further complicates the situation due to involvement of multiple stakeholders. In most cases their demands on product customization are wishes rather than actual needs. This problem is further fueled by Volvo Buses strategy to acquire number of different body builders and failure to consolidate them to form a standardized industrial solution. Because of which regional variation in products is created. As Volvo Buses operates all around the world in many diverse markets it needs to customize the products to match the demands of each market. This would still be feasible if they had a significant amount of volume per market, which is not the case. Thus it is established that, to cater the demand of customized-to-order products and still able to survive and be competitive there is a need of strategic flexibility. Based on the secondary research modularization strategies appear to be promising for the strategic flexibility required in such situations. But to check this claim it was necessary to evaluate those strategies against the challenges faced by core business process and organization because of the customization issue.

Results and Discussions II identified number of these challenges and side by side evaluated applicability of modularization strategies in those scenarios. A general view provides the evidence that product customization is agreed to be a challenge for the company. Some middle way to provide the customized-to-order products still keeping control on internal variety and complexity was felt necessary. Then the author followed the core business processes and involved functions to understand their current challenges. In almost all cases it was concluded that modularization could address those challenges. Some could argue that this thesis portraits modularization as the only best strategy to solve the problem. That is not the case and there could be alternative ways to address this issue. Modularization strategies are being discussed at Volvo Buses for a long time and based on the conclusions drawn from this research it is the most appealing approach in case of Volvo Buses. Thus the author decided to only concentrate on the modularization strategies to manage the development of customized-to-order products.

Results and Discussions III finally explores the previous and current efforts done by Volvo Buses to reduce the customizations upfront in the market and to effectively manage customization internally. Even though Volvo Buses tried to reduce the customization externally by removing certain model combination those efforts seems standalone and reactive. The detailed analysis of a current development Project X revealed the shortcoming in implementing modularization strategies in practice. Lack of knowledge about these strategies, missing organization structure and failing to incorporate the whole organization in these efforts were some of the identified shortcomings.

Results and discussions so far establish background for Customized-to-Order products, identify its challenges and evaluate modularization as a right strategy to deal with it. It also presents limitations of efforts done in this regard so far. These shortcomings will become basis for the future recommendations presented in next chapter.

9. Recommendations and Implications

This chapter will present the recommendations to overcome the shortcomings of currents efforts done by Volvo Buses to address the product customization issue. These recommendations are based upon the analysis of results so far and knowledge gained from secondary research. This chapter will also discuss the implications of these recommendations on Volvo Buses and its customers.

From the findings so far it is evident that Volvo Buses has to offer highly flexible products which require constant modifications and customizations in line with customer demands. So in that case the company should strive for product architectural strategies to meet the respective market situation. Based on the analysis and discussions of the current challenges for Volvo Buses, modularization strategies emerge as a suitable strategy to address those issues. But the problems identified with the current implementation of modularization strategies suggest that the company need to relook at the way these strategies are being implemented. On the other hand it is also possible to do more to reduce the customization externally with the customers. By keeping this in mind the author makes the following recommendations for both reducing customization upfront and for effective implementation of modularization strategies.

9.1 Reduce Product Customizations Upfront by Shifting Focus on Life Cycle Costs

The most obvious way of addressing the challenges in Customized-to-order scenario is to reduce the customizations upfront when the orders are being placed. Previous efforts done to reduce unnecessary product variants are more like internal cost rationalization project; they did not form an overall business strategy as such. Many of the interviewees pointed out that there is much more that can be done to convince the customer to go for more standardized offer. In quotes of Volvo Buses CEO Per Carlsson "Sell what we have, do not sell what we do not have". Even though the bus business is very conservative and customers are less adaptive to changes, everyone understands the language of money. Especially now as the customers, both in public and private segment are more concerned about lowering life cycle costs (LCC), and increasing profitability, Volvo Buses could take advantage of this situation. For doing this it is important to communicate a clear picture to the customer about the consequences of his chosen customization. If the sales person has a clear idea about what to promote and what not to promote he will naturally try to sell more favorable option. But to do this and avoid the confusion company first need to have a distinct product offer and supporting IT solutions like product configurators to build and compare different product cost scenarios.

Until now providing customized products as per any of the customer's wishes is the selling point for Volvo Buses. But considering the increasing challenges it puts on the business, the question is how long company can afford it. Volvo Buses is a major player in the bus industry and should use its position to introduce new trends in this industry. Bus business consists of a relatively small

community of manufacturers and customers. So if all the manufacturers decide to push for some standardized solution, there is a lot of scope and possibility for building mutual understanding.

As Volvo Buses aims to be a customer centric organization, it is necessary to differentiate between customer needs and wants. Based on the observations of previous customizations and nature of bus business so far, it can be said that most of the customizations are wants rather than actual need. In that case company has to challenge the customer requirements and even say no to some of the non-profitable orders. By not accepting all the customizations and sticking to more stable product offer, company could benefit in the longer run due to higher operational efficiencies.

9.2 Focus on Key Markets as well as Product Features and Streamline Global Product Plan

Before implementing modularization strategies it is important to know how many product combinations company actually needs. Evolution through years of product ranges and reuse of modules across different market regions ought to be carefully planned in order to exploit the advantages of standardizing interfaces without being trapped by its intrinsic stiffness. Today the product plans are more or less governed by products or engine installation projects. Many products at different locations overlap in terms of specifications and still treated as different products all together. These overlapping product specification create confusion in sales process and add unnecessary complications in overall operations. Due to the long product life cycle frequent product modifications and face lifts are common at Volvo buses. Today the new product development projects are bit standalone without proper coordination with these regular product modifications. Thus it is difficult to predict how the currently developed new product is going to be changed in future.

So the first step before implementing modularization strategies is to prepare a comprehensive global product plan. This product plan should give a bird's eye view of different product families, variants, market regions, new product introduction, planned product facelifts and modifications and interrelations between all these factors. Obviously it would be a very complicated task and what company can do to reduce this complication is to focus primarily on key markets/customers which can give sustainable business for a longer time. The current work being done to define the feature/technology roadmap could further aid in knowing what is most important for the customers. Based on these inputs a complete product offer could be chalked down.

If company succeeds up to this the next recommendation would be to stick to the plan. Today the product modifications or even the new product introductions are more reactive to the market. It means company loses control over streamlining the product offer by creating disconnected product variants spurring from random customer requests. So every time company faces such a choice careful comparison between impacts of accepting the modification and losing the customer is required to be

carried out. This has to be communicated and understood by different stakeholders to avoid internal conflicts and being able to stick to the plan.

9.3 Enhance the Knowledge about Customer Needs and Develop Modular Architecture

Although modularization promises to be a right approach for efficiently providing customized products, it requires a much higher level of knowledge and understanding about customers' needs and desires before its implementation. During the system level design stage of the product, company should try to collaborate and understand customer's exact desires and affections for the developed product. (Gilmore & Pine, 1997) Term it as collaborative customizations. The knowledge gathered during that phase could be utilized to develop the set of modules and interfaces that can be configured to various customers' requirements. This could guide the development of appropriate modular architecture which could provide required degree of product variety. (Ulrich K. , 1995) Suggest some questions company should find answers to before implementing modularization strategies, such as

- Which functional element will require upgrade in future?
- Which functional element may have to be adapted for customer needs?
- Which functional elements can remain identical for future models of the product?
- Which functional elements must change rapidly to address changing market demand?

Functional elements in this regard are the functions that the product or part of product is supposed to carry e.g. giving drive power to vehicle, provide the storage space for luggage. In these cases physical product components could be engines, racks etc.

In addition to finding out answers for these questions Volvo Buses could also utilize the knowledge base from years of customer adaptations. This is the transparent customization approach suggested by (Gilmore & Pine, 1997), i.e. customizing product proactively by knowing customer's preferences in advance. Today customer adaptations function is in a separate organization and their inputs for defining requirements for new product development projects are very limited. But by carefully studying past product customizations future product requirements could be specified in a way to already incorporate those needs.

Based on these customer collaboration and analysis of past customization Volvo Buses should decide on modular architecture and placement of interfaces. They should be developed in such ways that mix and match between predesigned modules could provide the global product offer decided as per previous recommendations. First step is to decide on total possible configurations e.g. deciding on number of seat layouts, number of door layouts, engine options, driver's compartments etc. The next step would be to replicate the same modular structure in documentation for easy interchangeability of modules.

9.4 Align Product and Organization Structure with Defined Roles and Responsibilities

The main problem identified during investigation of previous modularization implementation project was lack of supporting organization and confusion about the roles and responsibilities. Even though there was an upstream organization structure in form of product range management, the downstream organization structure to actually carry out the modularization work on operational level was missing. There are two common ways to structure the development organization.

The first way is same as Volvo Buses is organized today. Development organization is arranged according to the product's major technical subsystems, e.g. electrical, powertrain etc. In this way team members with similar skills and knowledge are grouped together which enhances the quality of innovation. When introducing modular product structure, major restructuring of the organizational set-up could also be omitted. But this setup does not provide the organizational grouping to minimize coordination demands. The decentralization of decision making cannot be realized, and this organization setup cannot develop the coordination capabilities because it lacks loose coupling. This was the evident problem at Volvo Buses as the development organization is spread globally. That was the reason company faced lot of issues for coordinating global product development during project X. Due to lack of coordination change in one component creates a chain reaction affecting the whole architecture which would result in destruction of modular architecture in long run.

According to (Sanchez & Mahoney, 1996) standardization of component interfaces specifications enables product development process to be loosely coupled. Thus for successful implementation of modularization, product and organizational architectures have to be aligned. In this way the technically separate components can be developed by technically separated organizational units. The recommended alternative is to mirror the modular product architecture with the development organization architecture. So in addition to functional organization, additional cross functional teams should be created in line with physical modules. It would significantly affect the organization and loosely coupled organization will emerge. The advantage of this setup is decentralized decision making and reduced need of managerial authority. The changes in one module could be resolved within module boundaries without affecting interface specifications, even in case of conflicts the two module leaders can meet and decide how to continue with the solution. In this way company can keep modular product architecture stable for much longer time. It is very essential because once the interfaces are designed changing them often would be very costly and resource consuming affair. So it is recommended to assign proper module responsibilities and establish routines and procedures to insure that the product development is in line with the modular architecture.

From organization point of view it is also necessary to increase the awareness of such strategies amongst the project members. Each person involved in these efforts must know the consequences of his day to day actions on overall success of these strategies.

9.5 Summary of Recommendations

Reduce customization upfront by collaborating with the customer and focusing on Life Cycle Costs

- **What is needed**
  - Differentiation between need and want
  - Understanding cost of complexity
  - Awareness regarding what to promote and what not
  - Clearly putting Life Cycle Cost of customization on negotiation table
  - Linking sales incentive to accepted customization
  - IT configurators for simulating product cost scenarios

Focus on key markets as well as product features and streamline global product plan

- **What is needed**
  - Focus on key markets and customers
  - Identification of most valued product features
  - Planned evolution of products globally
  - Product plan considering modularization
  - Sticking to the plan

Extend the knowledge of customer needs and develop modular architecture

- **What is needed**
  - Involvement of customers in concept phase
  - Reintegrating knowledge from regular customizations in new developments
  - Deciding degree of modularity
  - Design and development of modules and interfaces

Align product and organization structure with defined roles and responsibilities

- **What is needed**
  - Increasing awareness regarding modularization strategies
  - Mirroring organization with product structure
  - Module responsible with cross functional module teams
  - Guidelines for resolving interface conflicts
  - Establish routines and procedures for development

9.6 Implications for Volvo Buses and its Customers

First and foremost implication for Volvo Buses is to make the whole organization understand the need of implementing modularization strategies. The previous unsuccessful attempts done so far created a negative impression about these strategies in organization. The challenge for the management is to change this impression by showing commitment and support throughout the development process. In addition organization will need knowledge about what modularization actually is and how should they change their way of working to avoid the confusion noticed in the previous efforts.

Previous case study revealed that implementing modularization strategies and at the same time adhering to time, cost and resource constraints of the project were not working. Even though Volvo Buses cannot undertake such process improvements without connecting them to a new development project, an additional buffer of time, budget and resources is still required. Company also needs to understand that product modularization will not be successful unless there is supplementary organization structure. At the same time these kinds of organizational changes take years to implement, stabilize and start delivering the results. Thus expecting the overnight changes just through one project would be a bit over ambitious.

While implementing modularization strategies company has to be aware of the high initial costs and additional resources required to divide up product into modules and carefully design the interfaces. Also by using standardized interfaces and components across all the products some low range products could become expensive and in some cases company will not be able to transfer that cost to customers. They will of course be paid off later by realizing economies of scale and reduction in resource requirements in subsequent product introductions. Compared to these associated costs short term benefits of modularization are marginal and thus initial investment may take time to pay off. So during that period company might need to be ready for low profits or even losses.

Implications for the customers are a bit different in nature. These strategies are aimed to provide a rich variety of products to the customers but with some constraints. As the modules could only be changed between predefined ranges, customers might have to let go some specific customization requirements. But as author suggests customers could become part of defining the required product specification in early stages of product development. This would give them a chance to reflect on what customizations they are asking for and its long term effects. By knowing this the customer can focus more on the life cycle cost of the purchase and improving profitability by buying more standardized products. Volvo Buses might lose some customers by taking firm stand on not accepting some of the customization requests. Still in the end by being proactive, carefully focusing on important product features, and gaining advantage from increased cost performance ratio, in the long run company could successfully venture into newer markets and attract even more customers.

10.Conclusion and Future Research

The purpose of this thesis was to explore the background for product customizations in Customized-to-Order products, identify the challenges for core business processes as well as overall organization and finally in this context evaluate applicability of modularization strategies with possible implications.

Inherent customization culture in the bus industry can be tracked back to its build-to-order small scale local industry setup, which over the years has created fragmented product requirements. Recent developments in the bus industry in terms of privatization and business consolidation have prompted many previous chassis manufacturers to venture into complete bus business on a global scale. But due to the typical nature of the sales process and conservative customers, bus business is still not mature enough to go for an off-the-shelf product offering. As Volvo Buses operates in the global markets with diverse customer requirements it has to customize almost every aspect of the product. Extent of these customization needs could be judged by the dimensions of customizations identified during this study.

Investigation of challenges faced by the core business processes and overall organization clearly indicate the far reaching consequences of these customizations. This also means that Volvo Buses has to adopt some strategy to address these challenges and at the same time efficiently provide customized-to-order products to the diverse global customers. The findings of the literature study pointed towards modularization strategies as the right approach in such cases. By evaluating these strategies against the previously identified challenges the author was able to confirm the applicability of these strategies. Modularization strategies are not only advantageous during development of products but also throughout the complete value chain from sales to service. It could also resolve the organizational challenges faced by Volvo Buses today.

Modularization strategies are in the discussion at Volvo Buses for a long time and one of the recent development projects was aimed to implement these strategies. Volvo Buses is also trying to streamline the product offering by working with the customers and cutting down the product variants. While analyzing progress of these efforts the author identified certain limitations that lead to unsuccessful implementation. To overcome these limitations the author suggested number of recommendations ranging from collaborating with the customers to implementing modular organization structure. But before implementing any of these strategies Volvo Buses needs to understand the discussed implications on the company as well as its customers.

Finally this thesis was able to provide a comprehensive picture of background, challenges and managing strategies for developing customized-to-order products. This thesis could be a good starting point for all the future research to be carried out at Volvo Buses. The author recommends the following areas to be explored in continuation of this thesis.

Future Research

The explorative nature of this thesis opens up various future research possibilities. One of the recommendations to deal the customization was to collaborate with the customer to understand his exact needs and requirements. Due to the time limitation during this thesis, the author was not able to go out and talk to the customers or observe the actual sales process. But as almost every customization requirement origins in this stage a detailed investigation could bring the issues or customer expectations in more light. In conjunction there is also a potential to offer a service to the customer to arrive at optimum product specification. Thus a service development study could be carried out in this regard.

This thesis primarily focuses on modularization strategies as a solution to provide cost effective variety of customized products. But during the literature studies the author also came across platform strategies. Even though platform and modularization are two distinct strategies they could be mutually supportive. So a comparative analysis of implementing both the strategies in parallel or in combination could be carried out.

If the company decides to go ahead with the modularization strategies it would require carrying out numerous efforts for operationalizing these strategies by utilizing systematic modularization methods. As this thesis was aimed to explore the overall picture it does not cover the modularization tools or methods. Thus another future research could aim at the identification of various modularization methods and their appropriateness in the case of Volvo Buses.

References

Ahmad, S. S. (2010). The relationship among modularity, functional coordination, and mass customization implication for competetivenesss. *European Journal of Innovation Management*, 46-61.

Baldwin, C. Y., & Clark, K. B. (1997, September-October). Managing in the age of modularity. *Harvard Business Review*, pp. 84-93.

Creswe, J. W. (1994). *Research Design - Qualitative & Quantitative Approaches.* Thousand Oaks, California: Sage Publications.

Galbraith, J. (1973). *Designing Complex Organizations.* Boston: Addison-Wesley Publishing Company.

Gallardo, J. (1995). *Managing Configuration Options for Build-to-Order highly customized products with Application to Speciality Vehicles.* Cambridge: Massachusetts Institute of Technology.

Garud, R., & Kumaraswamy, A. (1995). Technological and organizational designs for realizing economies of substitution. *Strategic Management Journal*, 93-109.

Gershenson J.K., P. G. (2003). Product modularity : Definitions and benifits. *Journal of Engineering Design*, 295-314.

Gill, P. S. (2008). Methods of data collection in qualitative research : Interviews and focus groups. *British Dental Journal*, 291-295.

Gilmore, J. H., & Pine, J. B. (1997, January). The four faces of mass customization. *Harvard Business Review*, pp. 91-101.

Hamel, J. S. (1993). *Case Study Methods.* Newbury Park, CA: Sage Publications,.

Henderson, R. M., & Clark, K. (1990). Architectural Innovation : The Reconfiguration of Existing Product Technologies and Failure of Established Firms. *Administrative Science Quarterly*, pp. 9-30.

Holmqvist, T. K., & Persson, M. L. (2003). Analysis and Improvement of Product Modularization Methods : Their Ability to Deal with Complex Products. *Systems Engineering*, pp. 195-205.

Hvam, L. M. (2008). *Product Customization.* Springer.

Kahn, B. (1997). Variety : From the Customer's Perspective. In T.-H. Ho, & C. S. Tang, *Product Variety Management : Research Advances* (pp. 19-37). California: Kluwer Academic Publishers.

Krishan, V., & Gupta, S. (2001). Appropriateness and Impact of Platform based Product Development. *Management Science*, 52-68.

Lampel, J., & Mintzberg, H. (1996, Fall). Customizing Customization. *Sloan Managament Review*, pp. 21-30.

Meyer, M. H., & Lehnard, A. P. (1997). *The power of product platforms : Building value and cost leadership.* New York: The Free Press.

Mikkola, J. (2000). *Modularization assessment of product architecture.* Copenhagan: DRUID Working paper no 00-4, Department of Industrial Economics and Strategy, Copenhagen Business School.

Muffatto, M. (1999). Platform Strategies in International New Product Development. *International Journal of Operations and Production Management*, 449-459.

Muffatto, M., & Roveda, M. (2002). Product architecture and platforms: a conceptual framwork. *International Journal of Technology Management*, 1-16.

Pasche, M. M. (2011). *A Contingency-Based Approach to the Use of Product Platform and Modules in* NPD. Göteborg.

Persson, M., & Åhlström, P. (2006). Managerial issues in modularizing complex products. *Technovation*, 1201-1209.

Piller, F. (2007). Observations on the Present and Future of Mass Customization. *International Journal of Flexible Manufacturing Systems*, 630-636.

Ramdas, K. (2003). Managing product variety : An integrative review and research directions. *Production and Operations Management*, 79-102.

Robertson, D., & Ulrich, K. (1998, June). Planning for product platforms. *Sloan Management Review*, pp. 19-31.

Robson, C. (1998). *Real World Research : A Resource for Social Scientists and Practitioner-Researchers.* Oxford, UK: Blackwell Publishers Ltd.

Sanchez, R. (1999). Modular Architectures in Marketing Process. *Journal of Marketing*, 92-111.

Sanchez, R. (2002). Using modularity to manage the interactions of technical and industrial design. *Design Management Journal*, 8.

Sanchez, R. (2008). Modularity in Mediation of Market and Technology change. *International Journal of Technology Management*, 331-364.

Sanchez, R., & Mahoney, J. T. (1996). Modularity, flexibility and knowledge management in product and organizational design. *Strategic Management Journal*, 63-76.

Scavarda, L. R. (2010). Managing product variety in emerging markets. *International Journal of Operations & Production Management Vol. 30 No.2*, 205-24.

Shamsuzzoha, A. (2011). Modular product architecture for productivity enhancement. *Business process management journal*, 21-41.

Thompson, J. (2007). *Organizations in Action.* New Jersey: Ttansaction Publishers.

Ulrich, K. (1995). The role of product architecture in the manufacturing firm. *Research Policy*, 419-440.

Ulrich, K. T. (1991). Fundamentals of Product Modularity. *Proceedings of the 1991 ASME Winter Annual Meeting Symposium on Issues in Design/Manufacturing Integration.* New York.

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case Research in Operations Management. *International Journal of Operations and production Management*, 195-219.

Wheelwright, S. C., & Clark, K. B. (1992). *Revolutionzing product development : Quantum leaps in speed, efficiency and quality.* New York: The Free Press.

Yin, R. K. (2008). *Case Study Research - Design and Methods.* Thousand Oaks, California: Sage Publications.

Appendix I: Volvo Buses Global Product Offer

	Replaced by OBC				Säffle Wroclaw	Carrus Wroclaw	Mexico	Mexico	India	India
Chassis / Body	**B8500**	**B7700**	**B7700H**	**B8700**	**BX 900 "OBC"**	**B9700**	**BSTAR**	**B8300**	**B8400**	**B9400**
BRLH			7700H B5HL		7900 B5LH VH2.9					
R7				8700 B7R	8900 B7R VH3.1	9700 B7R CA at CARRUS				9400 B7R
R7LE	8500 B7RLE			8700 B7RLE	8900 B7RLE VH3.1				8400 B7RLE	
R9					8900 B9RLE VH3.1	9500 B9R		8300 B9R		9400 B9R
R9L + ENG-VE9		7700 B9L 7700 B9LA			7900 B9L VH2.9 7900 B9LA VH2.9					
R9L + ENG-VG9		7700 B9L CNG 7700 B9LA CNG			7900 B9L CNG VH2.9 7900 B9LA CNG VH2.9					
S9 Not replaced by OBC	7500 B9SALE 7500 B9SALF 7500 B9SALF Bi-Artic									
R11										9400 B11R

	Replaced by OBC				Säffle Wroclaw	Carrus Wroclaw	Mexico	Mexico	India	India
Chassis / Body	**B8500**	**B7700**	**B7700H**	**B8700**	**BX 900 "OBC"**	**B9700**	**BSTAR**	**B8300**	**B8400**	**B9400**
R12	8500 B12BLE			8700 B12B 8700 B12BLE		9700 B12B				
RXX+ ENG-VE13						9700 B13R 9900 B13R Exclusively in VPI	9700 B13R ”MEX” EM-EU5 9700 B13R ”DOT” EM-USA10			
M12								7300 B12MA + Bi-Artic as CA		
”8 liter Cummins CNG”									8400 8-liter CNG	
Chassis used exclusively by external body builder		• B9TL • B12R BR • BXR					• B5LH DD			• B12R 8x2

Appendix II: List of Interviews with Participants' Roles and Dates

Number	Roles	Dates
1	Project Manager Marketing for city bus	27-jan-2012
2	Project Manager Marketing for Coach	10-feb-2012
3	Product Director for Business Region Europe	14-feb-2012
4	Pre-studies and Planning (Product Planning)	14-feb-2012
5	Senior manager Public Affairs (Product Planning)	15-feb-2012
6	Product Director for Business Region International	15-feb-2012
7	CPM in Business projects	15-feb-2012
8	Vehicle Architect Coach	16-feb-2012
9	Chief Project Manager New Seats	16-feb-2012
10	Chief Project Manager Euro6	17-feb-2012
11	Vehicle Architect city bus	20-feb-2012
12	Customer Adaptation Manager	21-feb-2012
13	Project Manager Manufacturing	23-feb-2012
14	Project Manager Aftermarket	27-feb-2012
15	Chief Project Manager New Coach	29-feb-2012
16	Manager Advanced engineering	01-mar-2012
17	Group Manager for Virtual Packaging	02-mar-2012
18	Manager ABC and Product Costing	08-mar-2012
19	Product Director for Business Region Americas	14-mar-2012
20	Project Assurance Manager	02-apr-2012
21	Group Manager Project Management Support	17-apr-2012

Appendix III: Interview Guide

1. Overview.

1. Can you briefly explain the role and activities you are responsible for? Both in line organization and in new development projects?
2. What are your views about variety of products being offered by VBC?
3. Does business expansion in different countries/markets and moving from building chassis to complete vehicle had made an impact on complexity/variety?
4. How does it affect your specific function?
5. Have you encountered any issues/problems related to product customization in your day to day working?
6. What are your ideas about implementation of product platforms and modularization strategies at VBC?
7. How much attention do you think it is getting right now? Is it adequate? If not why? Is it underinvested?
8. What more can be done in this area? What is the ideal situation for you?

2. Market/ Customer.

1. Which are the different products being offered in each segment?
2. What is the connection between market segments, product families, variants? Is it easy to track throughout the process?
3. Is there is anything called standard or base model on which variants are built?
4. What is the market situation in terms of competition, trends, and stakeholders?
5. What is the selling point of Volvo compared to competition?
6. How competitors are dealing with standardization v/s customization?
7. Which is the major market segment where multiple customer adaptations are required? (Dependence on maturity of market)
8. What are the main reasons of different customer adaptations in products?
9. Who decides on how much customization can be offered?
10. How does marketing collaborates with the customer to identify exactly what he needs and provide perfect fitting products ?
11. How the products are communicated with customers? (Attributes based or alternative based)
12. Do customers care about commonality or getting a distinctive looking product? As opposed to automotive industry?
13. Is the sales person try to negotiate with the customer to go for a standard product solution?

14. What is the difference between adaptions required on chassis and complete bus? (In terms of frequency and cost)
15. Are existing products and processes are easy to adapt to changes? (Time, cost, quality)
16. How does this adaptation impact the cost? Who bears that?
17. Is there any feedback system to consider regular customer adaptations as standard product variants in future?
18. If customer appreciates the commonality or number of common parts across the range, are there any commonality initiatives driven by marketing?
19. What are the pre req's for new coach from commonality, customer adaptability or standardization point of view?

3. Product Management/ Product planning.

1. What is the input for product planning process? Overview?
2. Even though it is confidential can you give me overall idea about contents of Volvo Buses product plan?
3. Is it possible to make a reliable forecast about which products/variants/technologies are going to be in the future market situation? Say 5 to 10 year window?
4. What is a product lifecycle in bus market? How much is the gap between two consecutive new product introductions?
5. Are the variants are planned to introduced at the same time or released staggered? How the additions of variants affect the product plan?
6. What are the difficulties in product planning because of wide range of product variants? In future?
7. Is it possible to have clear differentiation and products tailored for every particular market segment?
8. Are these product plans take into account standardization across the product range? On what basis? (Architecture, processes, components?) CAST?
9. Is platform planning process, what is to keep common and what is differentiated is considered while making product plan?
10. Does product plan contain commonality or standardization across different brands?
6. Are there any synergies planned across different regions around the world? How the global v/s local product plan is balanced?
11. Is GBA -->Market segment--> Product Families--> Product Platforms per family --> modularized product --> Standard Solutions for each segment --> a good idea?
12. How is the product planning for new coach project is done?

4. Product Architecture/ Range management / Platform and modularization.

1. What is product architecture of complete bus offer?
2. What are the different types and the definitions? (High, low, city, coach?)
3. How many products variants?
4. Is product architecture is in-line with product plan? I.e. separate architecture for separate product groups?
4. Is it possible to identify cost of providing variety?
5. What are the current issues to use standardized components or modules across different architecture? What is CAST?
6. How frequently product changes from one generation to next?
7. How current architecture supports Customer Adaptations and Product Modification Requests without affecting much of other architecture?
8. How the commonality or differentiation is planned across different product families? Any process?
9. I heard that there is a talk about implementing platform and modularization strategy is there any target to standardize the components? Does current architecture support?
10. Which are the major modules identified that can be made common?
11. Is it possible to have clear interfaces between these different modules?
12. Is it possible to link single function to single module?
13. What about geometric nesting of components, how it affects modularized way of working?
11. How the interfaces are designed?
12. How much is the possibility to combine something with something?
13. How much impact production architecture (Assembly process) can make on product architecture?
14. In new coach project how the product architecture is different from current designs? What points are considered to make it adaptable to changes?
15. Is there is any consideration for future changes in products or modules?

5. Project management/ Requirements management.

1. While starting projects (start cost and PMRs) is there a clear linkage between product plans, current ongoing projects and future projects?
2. What is your general impression about project lead times/ time to market and do you think it is related to cross-functional product development?
3. Is the pressure of delivering projects with less time and cost is increasing? What the main issues to achieve this goal?

3. Do you think modularization approach can speed up the development process by reducing the rework of standardized parts/systems and focus essentially on unique developments?
4. Were there any pre.req. To reduce the variety and number of parts? What is final status?
5. How much CPM can influence the pre reqs. Regarding platform or modularization?
6. Is parallel development practiced or it is too complex to break down coordinate development tasks?
7. Platform or modularization strategies demand more emphasis on system level design; does current Global Development Process support this front loading of development activities? Systems engineering?
7. How the tread off between what to take into start cost project scope and subsequent PMRs is made? How It is insured that the subsequent PMRs will not result in rework or affect too much of existing development?
8. Is it possible to run a project with platform and modularization on focus? Is it possible to estimate and justify return on investments in longer terms?
9. How many requirements focus on commonality? Use of standardized components? How they are tracked? CAST target?
10. Are there any requirements for new coach in terms of product platform or modularization?
11. How these are handled through the Global Development Process?
12. How the tread off between commonality and variety is made? On what basis?

6. Manufacturing.

1. What problems manufacturing face in terms of unique part numbers, customer adaptations?
2. What are the overall views about having multiple customer adaptations?
3. What are the problems in terms of product customization and lead times?
4. Is it possible to achieve economies of scale with current level of sales and product variation?
5. How much flexibility manufacturing has to produce different products on same line?
6. What is the current assembly approach?
7. Is it going to be changed to modular assembly approach?
5. What are the advantages of that?
6. Does the current product architecture support this vision?
7. Is there any difference between product development modularity and modularity for manufacturing?

7. Aftermarket.

1. Any comments on number of different product variants, part numbers, and customer adaptations parts?
2. What is the overall trend and approach from aftermarket point of view for added complexity and promoting commonality?
3. Can you tell me how much that impact in terms of associated costs, service times, customer satisfaction, and warranties inventories?
4. How the part replacements are facilitated by current product design? Localized or need to change so many things?
4. What feedbacks have you received from customers for having unique parts?

8. Organization/Management perspective.

1. Do you think the current organization structure offers clarity in terms of who does what, and make it easy to achieve synergies and reduce waste, rework?
2. Do you think working globally in virtual teams makes it difficult to achieve synergies?
3. What can you say about development teams, close coordination or independently working?
4. What is the effectiveness of cross functional team working?
5. Is there any clear directive about commonality between offered products?
6. Is there any organizational unit responsible to insure commonality and work on platform projects?
7. How is the support from management while making tradeoffs for commonality v/s variety?
8. Is it difficult to justify the costs in platform projects as they have long term payback periods?
9. How is it insured that all the affected people are involved and informed when making major decisions about variants or commonality?
10. Is the project organization in new coach reduce the need of coordination but still achieve synergies?

9. Closing Remarks.

1. Do you think having a common platform with interchangeable predesigned modules with standardized interfaces is the ideal situation for bus business?
2. What do you think are the major challenges to achieve above goal?
3. From VBC Point of view how much difficult is to change an existing process or adapting a completely new way of working?