THESIS FOR THE DEGREE OF MASTER OF SCIENCE IN
INDUSTRIAL MANAGEMENT AND ENGINEERING, MECHANICAL ENGINEERING

PRODUCT SERVICE SYSTEMS AND
MODULAR DEVELOPMENT
*Implications and Opportunities in the Construction Equipment Industry*

by

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VOLVO

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Karlskrona August 2013
The job done about the Product Service Systems and Modular Development has been very well performed. The results covered a broad scope as the evaluation was done including multi dimensions (technical, strategy, organization, financial, etc.).

Tommy Streipel

Director, Wheel Loader Product Platform
Volvo Construction Equipment
Abstract

Volvo Construction Equipment is considering applying modular design to their organisation in order to constrain the growing intangible information and parts assortment within the company, and as well to enable a rearrangement of production, sales and logistics in the near future of organisational growth and industrial footprint. Hence the purpose of this thesis is to investigate the opportunities and threats of implementing modular design to Volvo Construction Equipment. The analysis is scoped on the generic aspects of modularity and the organisational weaknesses within Volvo CE towards implementing a new organisational structure, product design and production with modular design. Modularity enables the company to move towards decoupling the constraints of tangible sales and provides an opportunity to offer Product Service Systems as a Total Solution for each individual customer.

By implementing the authors common knowledge and education within engineering revolving tangible and intangible products and services alongside with innovation, together with informal interviews of stakeholders, the results of the thesis was reached. The analysis of the results was reached by implementing Design Research Methodology to the structure of the thesis, research method and interviews made. There is a distinct opportunity for Volvo CE to implement modular design since the informational flows, innovation, research and development is enhanced by a correct modular design. Although there is a distinct risk in changing a well-established product design, development process and organisational structure, the opportunities to create a product service system strategy and to re harvest and recycle value within the company with modularity outweigh the risk. Incomprehension of how to optimize a modular design may amplify the reasons why Volvo CE is considering revising their products and organisation with modularity, thus the authors recommend implementing a generic and specific education in modularity within Volvo CE to ensure a shared language of modularity and enhance traceability of the development within the company.

In order to enhance the organisational velocity around development, the authors also recommend a new computer environment which enables the different disciplines of engineering and marketing to modularise the product, services and processes while keeping the comprehension of the subject close to hand. This enables the organisational structure to change and improve towards modular deployment and to further accelerate Volvo CE’s growth, market share and revenue.

Keywords:

Statement of Contribution

This thesis is the result of a collaborative effort by Master Students, Andreas Blomqvist and Rickard Gustafsson. The opportunity to plunge into the topic of modular design was presented by professor Tobias.C.Larsson at Blekinge Tekniska Högskola and Tommy Streipel, with Volvo Construction Equipment. The students had previous knowledge of different development tools with the same kind of structure as Modular Development, but had never embarked in studies of modularity. Since the topic is quite vast, one of the opportunities was to inscribe two different disciplines within the thesis; Mechanical Engineering and Industrial Management and Engineering. This provided a broad analysis of the situation and topic. Although the disciplines were different, the authors have put their best effort towards contributing with their abilities to provide value for the results in both disciplines. Rickard Gustafsson has an understanding of tangible products and machinery while Andreas Blomqvist provided a wide knowledgebase on management and organisational structure, which resulted in a good understanding of the opportunities and threats of modularity within Volvo CE.

Through the development of the thesis the responsibilities and tasks have been distributed evenly between both members. Research Design, purpose and analysis of the situation and topics were conducted by both authors. The Authors would also like to acknowledge the tremendous contribution which the informal interviews with different employees at Volvo CE made to this thesis.

Andreas Blomqvist

Rickard Gustafsson

Karlskrona, Sweden, 2013.
Acknowledgement

This Master Thesis is the fruit of a collaborated thesis project between two Master students at Blekinge Tekniska Högskola, BTH, and Volvo Construction Equipment. The thesis is part of two different degrees in Master of Science in Engineering at BTH and would not have been possible without the tremendous support and education available from the employees at BTH.

Firstly we want to give our thanks and gratitude to our advisor and dear friend, Massimo Panarotto, whose support, feedback and reflections were invaluable to the result of the thesis and to our growth as engineers. Without his encouragement and time, we might not have succeeded in finalizing the thesis. We want to acknowledge the great work of Gunnar Erixon on modular management, which were a big part in our pre study.

We also want to express our outermost gratitude to our professor Tobias.C.Larsson who enabled the opportunity to collaborate with Volvo Construction Equipment in this thesis, and for being a role model, mentor and big inspirational force in our education and thesis. We also would like to thank and give gratitude to our industrial supervisor, Tommy Streipel, who supported us with an infinite source of inspiration and for his highly valuable guidance and assistance in providing funding and information to this thesis. In addition we are highly grateful for the support we received at Volvo CE by, Gustafsson Håkan – Global Marketing, Johansson Hasse – Product Planning, Thorsell Anders – Product Planning, which enabled us to understand the present, future and history within the company and products of Volvo CE.

Also we want to pay respect and give gratitude to; the tremendous support we got by the knowledge and help of Lars Ljung and Johan Sundh which enabled us to get a deeper understanding of the subject, and the knowledge and friends gained by informal interviews at the TC department at Volvo CE Eskilstuna, whom without the structure of this thesis would be significantly different.

For being helpful with general knowledge in the Volvo CE business and providing us with tips which aided us in the right direction, we want to thank Yan Zhang – Product Planning China, and for providing us with help regarding the academic structure of the thesis we want to thank Farnaz Motamediyan as well.

Our families, friends and loved ones deserve a big sincere thank you for their understanding, support and patience through the process of writing this thesis. A special sincere thank you goes to, Rebecka Östrand, from author Rickard Gustafsson; -Your infinite support, encouragement and love were invaluable to me during the process of writing.

And finally a cheerful and thankful thought goes to the Australian band AC/DC whose music helped us finalise the details of the thesis.

“"It’s a long way to the top if you wanna RnD” – Andreas Blomqvist and Rickard Gustafsson
Aug 2013
# Acronyms

<table>
<thead>
<tr>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>Business Opportunity Description</td>
</tr>
<tr>
<td>CBC</td>
<td>Customer Buying Criteria</td>
</tr>
<tr>
<td>DFA</td>
<td>Design for Assembly</td>
</tr>
<tr>
<td>DFM</td>
<td>Design for Manufacturing</td>
</tr>
<tr>
<td>DFS</td>
<td>Design for services</td>
</tr>
<tr>
<td>DFX</td>
<td>Design for X</td>
</tr>
<tr>
<td>DRM</td>
<td>Design Research Methodology</td>
</tr>
<tr>
<td>DSI</td>
<td>Dealer Satisfaction Index</td>
</tr>
<tr>
<td>GPCM</td>
<td>Global Parts Cost Management</td>
</tr>
<tr>
<td>GSO</td>
<td>General Service Operations</td>
</tr>
<tr>
<td>HoQ</td>
<td>House of Quality</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation and Air Conditioning</td>
</tr>
<tr>
<td>LRM</td>
<td>Less Regulated Market</td>
</tr>
<tr>
<td>MFD</td>
<td>Modular Function Deployment</td>
</tr>
<tr>
<td>MIM</td>
<td>Modular Indication Matrix</td>
</tr>
<tr>
<td>PSS</td>
<td>Product Service System, sometimes referred to as total solution</td>
</tr>
<tr>
<td>QFD</td>
<td>Quality Function Deployment</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>SOA</td>
<td>Service-Oriented Architecture</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths, Weaknesses, Opportunities, Threats</td>
</tr>
<tr>
<td>TCO</td>
<td>Total Cost of Ownership</td>
</tr>
<tr>
<td>VCE</td>
<td>Volvo CE Construction Equipment</td>
</tr>
<tr>
<td>WL</td>
<td>Wheel Loader</td>
</tr>
</tbody>
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1 Introduction

Emerging from the Swedish agriculture segment the Volvo Construction Equipment (VCE) company originates from the early Bolinder and Munktell Company whose respective founder ran mechanical workshops in the central of Sweden. Bolinder-Munktell was early pioneers in creating innovation and provided mechanical solutions for agriculture. Volvo CE bought the Bolinder-Munktell Company in 1950 and inherited the culture of innovation and adapting to the market (1).

Through the years, VCE has created a number of adaptive construction equipment machineries which has changed the construction segment significantly; innovations such as the articulated hauler and the present wheel loader. Today the innovative machinery e.g. the wheel loader plays a significant role of providing multipurpose-all around solutions to many applications while meeting the customers basic and other configuration criteria’s at different production sites. It is an agile multipurpose vehicle with the possibility of numerous different applications; e.g. re-handling, pallet fork, heavy object and recycling processes. The different products play a major role in emerging market segments, creating infrastructure and production in different construction segments. VCE has through the years incrementally improved the products to its present perfection, from comfort to fuel consumption. The future generations in the product range hence need radical innovation in order to excel in the construction equipment segment and a business plan that fit accordingly. However, the definitive method for deploying new innovations to the company is a tough choice which implies the company to decide what innovation process and practices to employ before adopting the innovation program (2).

During the last decades tailored product solutions has increased in most market segments and this has become the reality for Volvo CE in the construction equipment field as well. Innovative products and services provided to the customer’s needs are vital for the businesses to stay ahead of their competitors. Finding new methods to meet the customer needs have become important and resulted in manufacturers finding non-product solutions to reinforce the brand loyalty of the customer (2). Both tangible and intangible products and services make a grave impact on the customer value and customer loyalty, as well as on the company’s structure. Considering this a fundamental fact emerge; if VCE wants to be competitive in providing for the customer needs, they have to consider revising the idea of the “Best Practice” of production and development in construction equipment, because the tangible and intangible flows surrounding the present complexity of the company and product structure is inefficient.

Volvo CE is currently producing, marketing and redesigning over 200 different Construction Machinery, and acquiring related businesses when opportunity is given. The 200 different machines are being built by an estimated sum of over 150 000 parts which is growing exponentially each year. Additionally the product flora is supported by available aftermarket parts total to over 300 000 pcs and growing. Each product part is costing an average of approximately 15 000 USD, according to Global Parts Cost Management model (GPCM) (3),
additional to the intangible costs from maintaining a computer data storage and updates of the information in the storage. Volvo CE seeks to cut their costs in order to be competitive and strengthen their position on the global market as one of the top producers of construction equipment. Since the customer needs and desires has increased from simple product solutions with only the basic features, to complex machinery with features including cup holders and specialized hydraulic systems; so has the number of different details in the production (4). Managing the information surrounding all the parts and the cost have become a problem for VCE. The increasing number of part articles and models is not only a problem for VCE, but also for the customers. Ordering the proper equipment for each customer due to the vast amount of options is a complex task. Including the competitors product solutions, one can see that VCE is facing a challenge to present unique solutions that brings value to the customers, while cutting the costs and creating a sustainable business environment for the future.

In order to tackle the problems of handling vast amounts of information, as well as high product complexity and a diverging product range, since customer needs have been met with “ad hoc” solutions, VCE want to rethink their way of producing the products. The mentality and system revolving product development seem to favor new design over re-use of old solutions (5).

Modular design in the industrial segment is an approach of subdividing a product into a network of modular functions which can be explained as parts that are connected into a complete product. The modules can be independently developed and produced.

VCE is looking at implementing modular design as an opportunity to break old habits and excel in developing new products while using current solutions in a product network configuration, as well as lowering the number of similar solutions and articles within the product range. Decreasing the number of articles and finding new solutions from modular development, simplifies ordering, developing, designing, producing, using, reusing and maintaining the products (6). VCE’s objective is to connect the services with the modularized products in a way which suits the customer and increases the brand loyalty, thereby also increasing the sales and feedback from the customers which means that Volvo CE can evolve as an organization. Although there are many benefits with modular implementations, it is important to consider the risks of modular design – e.g. high initial investment, coordination complexity and a lack missing needs in development process - when assessing the implementation of new modular parts or reviewing existing modular processes.

Since VCE is seeking to adapt modular design it is crucial that an analysis of modularity in their current scenario is conducted. The incentive of modular design is to decrease the growing cost and complexity of information within the company, as well as to and from the customer. While modular design might reduce the growth of information and different similar solutions, an aspect of modularity one must consider is where the responsibility of the information is transacted to and the operational changes. When implementing modularity the process of production will change towards a split assembly where the final product will be sub-assembled in multiple assembly lines. Each sub-assembly has a dedicated development
team with the responsibility of the information regarding the specific sub-assembly concerned. Responsibility of the information thus is increased in a modular design environment since each module is set to be developed and maintained by a specific actor.

The modular architecture consider customer needs, cost-efficiency and company requirements/ability when determine product specifications. While cost-efficiency is a strong argument of implementing modular design, some companies tend to suffer when focusing too much on cost-value drivers and hence the customer needs becomes blurred. This can lead to lost market share and revenue. Including the customer’s voice in the development and realizing that there are customers of information and products both within and outside the company, is therefore an important part of module development. The implementation of new modules also requires a high initial investment. Thus visualizing and predicting possible returns and benefits is a necessity before redesigning processes in the organization. When new modules are introduced, the organization sometimes must apply modular design to products that otherwise would be less costly and simpler to produce without modularity. This could lead to reduced competitiveness for some products in the line ups (7).

Using modular design as a development strategy allows the engineers to work on specific modules with defined interface rules which allows for separated development. With well-defined rules, each module can be developed in teams of which has specific skill sets in their specific technical range. However, before finding the defined rules, the need of broader skill sets are needed across the machinery range to maximize the benefits of modularity. Both the design and developing engineers must have a broad technical understanding to find modular components for synergies. If the design team lacks this, the benefits of modularity might get lost (7).

Volvo CE strive to move towards selling products as a total solution, and thinks that the incentive of modular design might help to constrain the growing cost towards selling complex machinery, and capture the core values. The opportunity to move towards providing the customer with the function of products and services as a total solution, need a nimble way of producing and delivering the solution towards the customer in order to be beneficial for Volvo CE. Today the logistics and production is constraining the opportunity to move towards providing a total solution package. Modularity would enable Volvo CE to produce and deliver a system of products and services as a total solution, and manage the costs of research and development in the future. Since Volvo CE currently isn’t providing the opportunity to rent or lease their products to their customer, the decisions needed to change the business is complex and thus needs an analysis of the concept of providing a package of a total solution.

To ensure a profitable implementation of modular design into the organization, the informational flows in the organization’s network are important to study since the implementation might affect most stakeholders in both a beneficial and disadvantageous way. To understand the current issues in Volvo’s organization scenario, interviews with internal stakeholders is essential. The interviews in this thesis led the authors into the issues of the informational flows and concerning a modularization of Volvo CE Construction Equipment.
The objective of the thesis hence became to find guidelines and important aspects for a sustainable business strategy of modularity and total solutions, which connected the product, organization and the customer in a flexible way, and look at the perspectives of having modular solutions in the long run. In a mechanical engineering perspective the thesis has studied the internal and external consequences of having modular development in the business and in an industrial engineering standpoint the research has had the objective of looking in the need of the business environment when conducting modular development in the organization. In both cases it has been studied in the situation of Volvo CE’s business in a global level and individual perception. The study of employees viewpoint has been conducted on a regional level - from meetings - while the scenario of Volvos general situation have been conducted on a global level - from meetings and documents.
2 Purpose of the Research

VCE have been increasing their number of products, parts and solutions they are providing to their customers for decades, and with their current business model it have become unsustainable for them to control. Volvo CE strives to shift their way of producing the products and delivering them to the customer to control the increase of parts in the business. Preferable all production sites should be able to produce and deliver the entire product flora to lower the environment impact of Volvo CE and recapture capital in the logistic operations, since modularity seeks to rearrange the production and as a result there will be less material transferring. Hence Volvo CE has chosen to introduce modular design and a global project which seek to implement modularity in their business. The modularization project seeks to facilitate some of their present and future complications, e.g. handling information, unsustainable logistics and diverse production techniques.

This thesis research thus was set to answer the questions:

1. How can modularity help Volvo CE to meet the customers’ needs?

2. How does modularity add value to the products and to the customers?

3. What effects can modularity have on the service system and information flows within the business and the product?

The idea is to provide an understanding about the connection between Volvo CE, the products and the customer when developing the new business concept, and visualizing how modularity can add value to the product. Materials for the research have been self-discovered by the students from earlier and present studies and articles, but also from interviews with research experts who provided readings aligned with the scope of the thesis. The research employees at Blekinge Tekniska Högskola within this field of research are familiar with methods known to capture the technical, economical and customer aspects later to be integrated in the business plan of Volvo CE. The researchers and employees at Blekinge Tekniska Högskola thus where a key source in finding the direction of this thesis and the proper research materials.

The thesis project started in the early March and proceeded over the next sixth months until August. Volvo CE and Blekinge Tekniska Högskola helped to identify the benefits and disadvantages with the development of modular manufacturing and how it might function as a sales opportunity. The intention was to look at guidelines for future process development in Volvo’s organization by including the internal and external customers of Volvo CE. Some of the information and documents used in this thesis are confidential material and has therefore been excluded in the thesis according to the confidential agreement.
3 Research Design and Research Approach

The approach of the scientific analysis in this thesis was conducted using Design Research Methodology (DRM). The method of DRM aligned very well with the parts of the thesis and research methodology in studying the effects of modularity implementation within the business of Volvo CE.

Design Research Methodology uses a four step approach of studying and analyzing a design problem, e.g. a modular design problem or a business design problem. The incentive to contribute with studies on practical scenarios also aligns with the DRM approach. Hence, the choice of applying DRM to the thesis project was evident.

The four stages of Design Research Methodology are described in Figure 3-1 and is an explanation of the method used in this project.

![Design Research Methodology Framework](image)

This thesis had two different scopes including both an analysis around the methodology of generating a modular design and an analysis around the impacts of modular implementation on the business network and the development of the machinery. Both research fields used the DRM approach. The research questions used in the project were answered during each process and while each research study had its own specific questions and objectives. The research questions and objectives were general enough to be included in each field of research, and hence the analysis was coherent.
3.1 Methodology

During six months, this project examined the impacts of modular design integration at Volvo CE; including both benefits and disadvantages into the study to find options and solutions to integrate modular deployment. Based on data collection from interviews and workshops with managers and engineers at Volvo Construction Equipment together with comprehensive literature review, the project group analyzed the processes of modular design integration and how it can affect the organizations business case. The process was executed according to the DRM approach since it aligned with the thesis project, Figure 3-2.

![Figure 3-2 Synopsis of the methodology process of the research using a DRM approach](image)

Previous to this thesis project the authors had a deep understanding of customer satisfaction and value innovation in industrial organizations, but limited experience in modular design development. Consequently literatures were reviewed in the subject to enhance the knowledge of modular development in industrial business, before locating the objectives of this thesis with Volvo CE. The objectives were set to match both the mechanical engineering and industrial management perspectives of modular development in businesses.

Phase 1 - includes the thesis review and meetings with managers at Volvo CE to acquire an understanding of the current and future situation at Volvo CE. Collection of data through corporate documents was obtained during this phase of the research process. Since the examination embraces two aspects of module implementation in Volvo’s business, the topics were studied separately later to be discussed between the students due to the depth of the topic of modularity and the need of understanding all aspects.

Phase 2 – includes the analysis of the modularity implementation methodology and the impact on the business network. Studying the general information collected from phase 1, this led to the analysis of the current situation and place of modularity within the scenario of VCE. The validity of the analysis was established by consulting the managers at Volvo CE revolving the aspects which were found. The managers consulted held key positions within Volvo CE in product planning, development, strategy and marketing and their opinions of different analysis within Volvo CE holds great value towards making decisions around the company’s future actions.
4 Literature Review

This chapter is dedicated to give the reader an understanding of the topics in modular design concerning the business network and modular development of products. It is structured around academic research of modularity and network design.

4.1 Modular Development

Professor Gunnar Erixon (9) state that the definition of a module is; “a functional building block with specified and standardized interfaces chosen for company specific, strategy reasons”.

A module is a feature or function with predefined interfaces or architecture to its surroundings. A module is able to work as an actor in a larger network and simultaneously function with other modules in the network to achieve results as a single product (9). When designing for modularity it is thus important to design an outcome, since different underlying requirements crave for different interfaces and architecture in between the modules (10).

A simplistic way of introducing the term modules and modular interfaces is to take the example of a toolbox and visualize it as a modular product. The entire modular networks function, the products function, is to “enable” the user to satisfy different needs when providing multiple functions/modules. Each individual module is a specific tool, like a screwdriver or sledgehammer. Every module, tool, has a very specific function and an interface towards the network i.e. toolbox. In this case the interface of the module is the hand of the craftsman and the size of the tool, since it needs to fit inside the toolbox and be able to be “used” by the hand of the craftsman.

The modular product, the toolbox, consists of multiple modules, tools, with a set of interfaces, size constrains and grip. Together, all the modules with the right interfaces act in the network, toolbox, in order to deliver the products function towards the customer, Craftsman/user. Depending on the customer requirements each toolbox company may connect the different modules in different settings to deliver a modular product fitting to each customer. The modularization of the toolbox might be driven by different sets of customer requirements depending on the targeted market of the company.

There are previous research and real life examples where a platform or modularity structure to the product and surrounding services have decreased the lapsed time and cost during the developing stage and increased certainty in market success, see Table 4-1.
<table>
<thead>
<tr>
<th>Company</th>
<th>Year</th>
<th>Old solution</th>
<th>Modularized solution</th>
<th>Effects</th>
</tr>
</thead>
</table>
| **Scania Trucks & Buses**   | 1980-1988 | Both right and left version details to their dashboards.                                                                                                                                                       | Dashboards modularized:  
- Middle console (left and right version)  
- Three consoles that are modularized to fit both left and right  
- Dashboard details (buttons etc.)                                                                                                                 | - The maintenance has become easier  
- The amount of rework reduced by 75%                                                                                                                   |
| **FMG Timberjack AB**       | 1991   | Three production sites (Joensuu, Filipstad, Alfta) for three different product families.                                                                                                                                 | Modularized chassis, engine, brakes, crane etc.  
Focusing detail and module production to one location (Alfta) and assembly in another location (Filipstad). The production of forwarder machines were focused in Joensuu. | - Assembly time reduced by 33%  
- Production of details have reduced its throughput time by 50%                                                                                       |
| **Electrolux AB**           | 1992   | The mechanical workshop produced the plate sheets for all parts in the company.  
Each assembly was structured in a traditional production line.                                                                                                                                              | The mechanical workshop was divided to produce a specific module.  
The assembly line orders the modules they require through the kanban-principle.  
The modules can be combined with a degree of choice to satisfy the customer needs.                                                                  | - Lead time reduced by 60%  
- Number of articles reduced with 25%  
- Increased quality  
- Improved logistics                                                                                                                                |
The theory that modular design provides positive results of total flows in business is supported by many researchers and practitioners, i.e. (13) (14) (15) (16) (17). The incentive to pursue modularity in order to strengthen the return of investment, product flexibility and competitiveness is self-evident to decrease the exponential growth of information and will affect the way the company works towards operations, customers and sales.

The Corporate Execution Board (7) has defined an overview of specific advantages and disadvantageous with modular design which needs to be considered.

<table>
<thead>
<tr>
<th>Specific Advantages</th>
<th>Disadvantages</th>
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</thead>
<tbody>
<tr>
<td><strong>Research and Development:</strong></td>
<td></td>
</tr>
<tr>
<td>Increased reliability</td>
<td>High Initial Investment</td>
</tr>
<tr>
<td>Reuse of design and materials</td>
<td>Lack of Customer-Centricity</td>
</tr>
<tr>
<td>Diversification of product lines</td>
<td>Coordination Complexity</td>
</tr>
<tr>
<td><strong>Manufacturing:</strong></td>
<td></td>
</tr>
<tr>
<td>Assembly line reduction</td>
<td>Supplier Risk</td>
</tr>
<tr>
<td>Changeover cost reductions</td>
<td>Low Flexibility for Exceptions</td>
</tr>
<tr>
<td>Shared process planning</td>
<td></td>
</tr>
<tr>
<td>Agility and flexibility</td>
<td>Intellectual Property Risk</td>
</tr>
<tr>
<td><strong>Procurement:</strong></td>
<td></td>
</tr>
<tr>
<td>Inventory reduction</td>
<td></td>
</tr>
<tr>
<td>Improved supplier management</td>
<td></td>
</tr>
<tr>
<td>Increased supplier design collaboration</td>
<td></td>
</tr>
<tr>
<td><strong>Marketing and Sales:</strong></td>
<td></td>
</tr>
<tr>
<td>Increased customization</td>
<td></td>
</tr>
<tr>
<td>Incremental upgrades</td>
<td></td>
</tr>
<tr>
<td>Quicker service and repair</td>
<td></td>
</tr>
<tr>
<td>Faster time to market</td>
<td></td>
</tr>
<tr>
<td>Simpler sales process</td>
<td></td>
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</tbody>
</table>

In Research and Development of a product, modern industry considers a new idea or an innovation to be a network creation due to the engineering of a solution. Each solution contains multiple analyses of mechanical aspects, economics and adaptation of design and product, in order to successfully be delivered to the market. An engineering project is currently a well-defined problem that has emerged due to sales, operations, customer requirements or competition. Modularity strives to split a complex product into a more manageable system of inventions or parts, and to lower the amount of parts involved in the assembly. When a modular design is applied to a product, all aspect of the products life is considered. Mechanical aspects, economics, future plans of the product and adaption designs are topics when the modularization is conducted. Modularity thus leads to opportunities with new ideas, innovation and inventions as often new ideas are new configurations that previously haven’t existed in its surroundings. Ideas that lead to innovation usually have to
Hibernate and evolve through communication with actors, customers, users and developers in order to breed new innovations (18). Modularity thus create new possibilities which lead to new products with differentiated market segments and innovations within both product development as well as business development, since modularity enables configurations that previously didn’t exist.

If the modular design evolves new customer requirements but remain in a steady state, revenue increases since a new differentiation not necessarily needs a new function/module to be invented; merely new configuration of the modular system. Reusing existing solutions with modularity hence saves time, investment and enables new markets to evolve. Reusing ideas, investments and parts gives preeminent impacts on sustainability of the operations, since waste reduction is used to develop business.

Good ideas or products usually originate from parts that are available from its surroundings and environment, much like the first wheel loader. Combining modular design with different aspects of product and business planning simplifies the product development and planning of correlated system changes (5). Finding virtuous module solutions can be a difficult task for a company; objectives that carry the company forward should be included when designing for modularity: e.g. sustainability, return of investment, development and customer satisfaction. Products derived from or that exist with modularity hence should be designed with the mentality of, who will; choose the product, use the product and inevitably pay the dues of the product.

Subsequently it should be hard to use the modularized product wrong since the modularity acts to improve the system and hide its complexity. And since “there is no such thing as a dumb user - only dumb products” (10)- it’s crucial that the right modularization is designed with more than just the end-users in mind. Users might be personnel within the company or function as actors during the developing and production stage of the products life span. Ownership of a module or an interface hence must be easy to understand, operate and implement if a modular design should be able to evolve further than just the first modularization of the product. Modularity in a business idea tends to lead to modularity of the user, by the user and for the user. While modularity is normally a tool for cost reduction, it is also a tool to develop products and services for the user in that essence.

Even though modular design seeks to benefit all customers external as internal, and the different valuable aspects to the different actors might not cohere; meaning that the business design needs a configuration that benefits the development of modularity business in total. With manufacturing, distribution, actual use and appearances in mind when structuring the product and the business plan, modularity can help a company to excel and inspire customers to help improve the products of the company (19). Ideas that might help modularity in the right direction could be the actual profitability of the modularized product in use, in system use and in the producing company’s use. One might consider remanufacturing on a wider world scale and cycle times as well as providing the possibility of product service systems to the end user.
4.1.1 Modular Design

The aspects of creating and producing a product, and delivering it to the market are the essence of any product development. The clash of economy of scale and economy of scope is an aspect for any growing and competitive company. The customer and company need isn’t always aligned, and a company that isn’t able to change the direction to align with the market demand is sure to lose market share. Agility in the product, production, marketing and logistics of a company hence is of great value to both the customer and the company.

The manufacturing systems agility doesn’t lie within the production equipment’s ability of the different factories, but within the architecture of the product being produced. The architecture also determines how the derived modular product can be changed in order to fit to the amount of varying requirements that might occur during the lifetime of a product.

Enabling the product and the company with modular design implies that the functionality of the product and company is kept to the greatest extent possible and the assembly is divided into subparts. Since the subparts are broken down by functionality it means that each sought function of the product and company can individually be produced, tested and developed. This lowers lead times both in production and development, and it simplifies customization. Parts and functions that commonly are subjects to customization can be placed in a way that renders the assembly of the custom product or operations simple and fast. Investments of customization work thus are lowered.

<table>
<thead>
<tr>
<th>Effects</th>
<th>Product Characteristics</th>
<th>Metrics/Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Development</strong></td>
<td>1. Lead time in development</td>
<td>Interface complexity</td>
</tr>
<tr>
<td></td>
<td>2. Development costs</td>
<td>Share of carry over</td>
</tr>
<tr>
<td></td>
<td>3. Development capacity</td>
<td>Share of purchased modules</td>
</tr>
<tr>
<td><strong>Assembly</strong></td>
<td>4. Product costs</td>
<td>Assortment complexity</td>
</tr>
<tr>
<td></td>
<td>5. System costs</td>
<td>Share of purchased modules</td>
</tr>
<tr>
<td></td>
<td>6. Lead time</td>
<td>Number of modules in product</td>
</tr>
<tr>
<td></td>
<td>7. Quality</td>
<td>Shared of separately tested modules</td>
</tr>
<tr>
<td><strong>Sales/Aftermarket</strong></td>
<td>8. Variant flexibility</td>
<td>Multiple-use</td>
</tr>
<tr>
<td></td>
<td>9. Service/Upgrading</td>
<td>Functional purity in modules</td>
</tr>
<tr>
<td></td>
<td>10. Recyclability</td>
<td>Material purity in modules</td>
</tr>
</tbody>
</table>

Table 4-2 Effects, product characteristics, metrics and rules for a good modular design (9)

Changes in a products design nearly always involve redesigns of the production system. Inevitably the changes are often carried out when the factory is shut down and this causes downtime. Hence the possibilities to release new products entirely depend on the available time slots to reset or redesign and implement new production systems or major product changes (20). It’s crucial that the redesign of a development process and modularization of a
product consider the entire lifecycle of a product and surrounding services, if the process should be run at an optimum. Inputs from the customer and engineers hence carry great intangible value for the customer, the company and by extension for the product. Erixon has found effects, product characteristics, metrics and/or rules that are necessary to include when designing for modules, see Table 4-2.

Modular design provide the opportunity’s to sequentially make changes and updates to products and production facilities in a working state of the operations. Modules may be simultaneously assembled and tested which enable faster and better quality product assembly and end product. When the lifespan of a product is vast, there’s strong probability that a modularization would increase the “update rate” of the product and present great opportunity’s to add on services and intangible modular products. Hence worth mentioning is the aftermarket of a product. When the lifespan of a product is vast and the life cycle is partially repeated, usually more than a primary and secondary life in different applications and customer segments due to inherited ownership or sale of a product, there might be a substantial renewal process of the individual machine through its life span. With modular design, each function that is subject to the renewal may be incrementally improved and the secondary life value is increased. The information flow from the tangible product and customers back to the mechanical engineers thus is a crucial part of error analysis and development. And in a modularization process that information is returned to the process of the product so fast updates to the coherent or colliding needs of the functionality within the modular company can be detected and used for development.

4.2 Modular Function Deployment and Conducting a Modular Design

Today a wide variety of different products is required by the customer, and each market seems to require a specific alteration of each product. As a consequence this leads to greater problems for satisfying the customer requirements and setting up the production to each site and market. Modularity strives to create products within the products, and it enables the production to be set up as factories within the factory. Having factories within the factory also means that logistics and production planning is able to be set up in a more agile way.

Traditionally when seeking a modularity of a product, Modular Function Deployment (9) is used with modular drivers scoped from managers who seek tangible measurements to improve their company. The MFD process, explained in section 4.2.2 to 0, conducts a matrix analysis from different aspects and goals to meet, and the best practice used in the company’s active market segment. Usually this means that the company dissects the competitors’ products and revises their own design within their products or production units.

From a company perspective it may seem interesting to standardize the production from a cost and quality perspective, hunting down cost to bring price down related to existing quality but the process often bring complications to the table when marketing and customers end up in
conflict due to expectations. Modular perspective on products and business implement a crucial reasoning that a comprehension of the mechanics of providing and selling a solution to a customer starts with customer need and consists of understanding the supplied value towards the customer.

This consequently means that adapting to market demands is more than to cut costs, amplify quality and drive lean production, it means that Companies need to understand where variety actually is needed and bring value to the business. When this is part of the internal reasoning of the business, additional standardization and internal improvement of the production is possible since it won’t constrain the ability to provide for the customer and company needs. Hence a modularization strategy will embrace the market complexity and simultaneously simplify the mechanics of the company product offerings (11).

Modular Function Deployment has the ability to show how to solve complex problems in the process of adapting to modularity and uses a cross functional product design. A Cross Functional product design approach is designed with different aspects in mind e.g. manufacturing, customer needs, development and aftermarket service. The end result driven from the MFD process is a modular cross functional design to their products and a direction for the company made by managers to set the direction of the company’s future in order to be modular.

MFD is one of the first methods to meet the product structure boundaries to the manufacturing boundaries and strategies of a company, while catching the requirements of all involved actors. The MFD method is composed of five steps to design a product flora, and to divide it into a number of internal and external modules. The modules then can be shared and combined or purchased among all the involved products of the flora, and end up as many variants keeping the involved parts at a minimum. The modularisation allows the manufacturing cost to be kept at a minimum compared with the diverse complexity of the number of variants of the product, while still enabling the company to have flexibility in the operation of sales and management.

MFD focuses on the strategy of the corporate company regarding the core competence and preparation for changes in technical abilities and processes within the company. Depending on different aspects of importance in the strategy for the company’s products, the modularisation may be structured and designed in a number of different ways. MFD creates a common understanding of the product and corporate strategy within the internal divisions of the company and enables designers, developing engineers, manufacturing personnel to work together to create the best end result. This means that modularity is enabling change and increasing developing capability in the product floras variety and the customer/market diversity.
4.2.1 The Concept of Modular Drivers

A modular driver, see a list of the generic drivers in Table 4-3, is a driving aspect of why the company have chosen to rearrange their product, or offering. In order to rearrange a product the underlying reasons needs to be implemented in a consistent way to ensure that all specific points of the modularisation is capsule in the result. The modularity created derives from the ability of each company to rearrange their market scenario, product and factory setting to ensure customer satisfaction. The modular drivers can best be explained as the underlying criteria’s of why the modular design is conducted. Generic Modular Drivers have been found via research in the Swedish industry (21), but specific modular criteria’s can be found in specific market segments or scenarios. The essential reasoning is that each modular driver needs to fit each company’s strategy, ability and business plan.

4.2.2 Clarifying the Product Specification - MFD Step 1

The first step of a MFD process is to define the specific customer requirements. To be certain that the customer demands are fulfilled when designing your product modularity, the first step is to make a quality function deployment also known as a QFD or House of Quality analysis (22). The crucial part of the MFD analysis which makes it different from a traditional QFD is that a modular structure to the product is the first design requirement in the analysis, hence MFD should be deployed if the company seeks to modularize their products. Otherwise MFD and QFD are similar. In a mature product the first step is usually left out since the design team assigned to modularise a product usually are senior engineers and developers and are well aware of the products design requirements and the customer’s needs and wants. Thus the first step of the MFD process is left out but not ignored.

![Figure 4-1 The five steps of the MFD process (23)](image-url)
4.2.2.1 **QFD-Deployment**

Quality Function Deployment (QFD), sometimes called House of Quality (HoQ), is a quality improvement tool that has been developed in Japan to translate customer requirements into appropriate technical requirements. Since its initial development in Japan it has been implemented all over the world for various stages of development in products, services and production (6) (24).

Many studies have been done in the subject and practitioners have established a vast number of papers. Chan and Wu have established a reference bank with about 650 QFD publications, ranging from the product design sector to the service provider sector; for more information of QFD deployment for services see Appendix 2: QFD-Deployment for services and the Kano Model. Today, it is hard to find a business where QFD has not been applied into practice and the tool has no definite boundary for potential fields of application. It is a great tool for proactive development early in the development process. Problems can be found and solved early on so that fewer people have to deal with the defects of the system or the products at later stages. It can work as a great planning tool and studies have been conducted in the fields of business planning, product planning and service quality planning (24).

Since the QFD was developed, many alternative reformed QFD processes have evolved with different specific topics in mind. Examples of this is Modular Function Development which uses QFDs with modular drivers included as a supplement which affect the final weighted results based on how well the functions correlate to the drives (6). Modular Function Deployment is a process which uses QFD and a Modular Indication Matrix (MIM); see Figure 4-5 for an example, which analyses to examine the interrelationship between module drives and technical solutions (11) (9).

Still, each methodology aim to increase the value of the customer and the object is to design the product, business and services with the customer in mind which subsequently increases the sales for the business. Designing the business in a way that constantly care about the customer and uses the feedback in an optimal way is the key to success and that is why QFD can work for services and business design development as well (6).

The basic QFD that is being used today is divided into a total of six steps, see Figure 4-2, and results in weighted importance of improvement of each technical requirement that is based on the importance of each customer need and its correlation with the technical requirement. Each step is explained further below.
1. Customer requirements

The first part of the QFD matrix is the most important one. The process uses a structured list of a customer’s requirements described in their own words - the voice of the customer. This voice states the requirements gathered from needs findings and i.e. interviews with the intended customers. The requirements must be structured in such a way that the requirements are affinitive and built into families of functions. The need finding process can be conducted in several ways, from interviewing the affected customer about their buying criteria’s of the product, to asking random people in the city about their thoughts of the product or company. Any process of finding customer requirements is appropriate if the process is conducted in such a way that the intended customer's voice is captured. Output from this first step might look as following.

- Light weight
- Low cost
- Good looks
- Machine can lift heavy objects
- Easy to steer in tight spaces
2. Planning Matrix

The planning matrix quantifies the customers’ requirement priorities and their perception of performance in an existing product. It also allows these priorities to be adjusted based on the issues that concern the product planners. These data are usually gathered from customer questionnaires. The importance weighting is of great value, usually done with numbers one to five.

- Light weight – 4 points
- Low cost - 5 points
- Good looks – 3 points
- Machine can lift heavy objects – 5 points
- Easy to steer in tight spaces – 4 points

This step also describes the relative importance of each of the customer requirements from the customers own perspective. This measure will be described in a column to the right and contain competitor’s performance and company alignment strategies as well.

3. Technical requirements

In this section the engineering characteristics of the Voice of the Customer is described, defined as measurable factors. This is done by a project group of engineers, developers and managers sitting down and looking at what aspects of the product that correlates with the customer requirements. It also contains a section where an illustration is made in which direction these variables need to change in order to consider the product improved.

4. Interrelationships

The main body of the analysis tool has the purpose to relate the requirements of the customer to the technical aspects of the product. This matrix relates the technical requirements to the customer requirements by having the design team or a test group rank them with points of one, tree or nine. It is crucial that the intersecting requirements are identified. Each of the assessed interrelationships is assigned with a score. The relative values of these weighting scores are chosen to suit the project.

5. Roof

The roof of the HoQ is used to identify the intersections where technical requirements that characterize the product support or impede each other. “Pairings” of technical requirements are considered. They are to be rated positive, negative or blank. This assures that the solutions chosen to fulfil a
specific customer requirement doesn’t have a negative impact on the design of the product overall.

6. Targets

The final section of the analysis summarise the conclusions drawn from the data collected to the input. The output consists of tree aspects, Technical priorities, competitive benchmarks and targets for the future. A mathematical assessment of the different targets is conducted to create tangible goals of the analysis.

Detailed information about how the QFD process is conducted can be found in the book “Total Quality Development” (22).

4.2.3 Analyse Function and Select Technical Solutions -MFD Step 2

The second step of the MFD is to find technical solutions to the modularisation. The output from the first step is the basis when the technical solutions are to be decided. By breaking down the products properties into functions, associated technical solutions can be found. The second step consists of two parts, a functional decomposition and a ranking matrix if the product is being designed from scratch. If the product being modularised is matured, only the functional decomposition is needed, since the products solutions already is sought to be the best.

Usually when the functional decomposition is carried out the method of Suh is used (25). The functional decomposition strives to connect the different functionalities within the products parts in a hierarchy to sort the products desired working aspects and functions.

When a new product design are up for modularisation, or the modularisation strive to connect many different product-types, there may be questions revolving which technical solutions and functionalities which best fulfils the correlating customer’s requirements. To be able to sort among all the solutions and find the ones that is the best suitable for fulfilling the products specification and functionalities, a Pugh matrix can be used. In the Pugh matrix the technical

![Figure 4-3 Example of a functional decomposition of a vacuum cleaner (26)](image-url)
solutions are sorted in a column and all the different product specifications that have been found are sorted into rows. By comparing the solutions to each intersecting product specifications and whether the solutions fulfil the specification a ranking from 1 to 5 is made. Hence a score for each solution is found and makes it easy to see which one is the best alternative.

<table>
<thead>
<tr>
<th>Rank 1 -5</th>
<th>Solution 1</th>
<th>Solution 2</th>
<th>Solution 3</th>
<th>Solution 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification 1</td>
<td>3</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Specification 2</td>
<td></td>
<td>4</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Specification 3</td>
<td></td>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Specification 4</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sum</td>
<td>7</td>
<td>8</td>
<td>9 Winner!</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure 4-4 Pugh Matrix Method

4.2.4 Identify the Possible Modules using MIM – MFD Step 3

The third step of MFD is about generating the modular concepts. Technical solutions found from the previous step, are analysed regarding their reasons for being separate modules. The technical solutions with the same correlating modular drivers are clustered together in a Module Indication Matrix and a first sketch of possible modular solutions is generated.

The heart of the Modularisation work is the Modular Indication Matrix. In this matrix the technical solutions from the second step are weighted against pre-determined modular drivers. The driving force of modularity is the modular drivers; they can be determined by managers in pre-workshops to the MFD process or the design team can use the generic drivers researchers have found to generate solutions in the industry. Based on case studies in the Swedish industry, Östgren (12)have identified twelve generic drivers;
1. Carry-over; an item in the product can be re-used in upcoming product generations.
2. Technological evolution. Items that is likely to go through a technological shift through its life cycle in the product.
3. Planned design changes, items that is likely to be changed during the lifecycle according to product planning.
4. Technical specification is an item that is subject to customisation and variations.
5. Styling. Items that are influenced by trends and fashion, and are easily altered.
6. Common units. Is an item that is used throughout the entire product flora (e.g. cabin).
7. Process and/or Organisation re-use. A specific process is needed or it has suitable work content for a group.
8. Separate testing of functions, before each item is supplied to the main operation.
9. Supplier offers black box, the item is designed and manufactured by a contracted supplier.
10. Service and Maintenance, the service and repair of the item will be easier if easily detachable.
11. Upgrading, the item can be rebuild or remanufactured to another configuration.
12. Recycling, items that are environmentally hostile and are to be kept separately in a module to simplify recycling.

Table 4-3 Generic Modular Drivers (12)

All these twelve generic modular drivers can be divided into sections of;

- Product development and design of the product; 1, 2 and 3.
- Variance; 4 and 5.
- Production; 6 and 7.
- Quality; 8
- Purchasing; 9
- After sales; 10, 11 and 12.

In a matrix structure every technical solution are tested against every module driver. The analysis consist of determining whether there is a strong, medium or low incentive for the technical solution to be carrier of the modular driver. The calculation are made in the same way as in the HoQ analysis where Strong = 9, medium=3 and low =1.

The number of module candidates is picked out as function carriers. Usually the square root of the average number of parts in a product variant is the ideal number of modules in the product (27) but the calculation is only a guideline, there may be both more or less modules. E.g. a vacuum cleaner consists of an estimated number of parts to 70 pc’s. This gives a probable ideal number of modules to be close to 8.

Considering the previous steps in the analysis the candidates then is ; Fan, Electric motor, Chassis, Bag, Filter, Triristor + knob, Housing and Wire Collector.
The technical solutions with the same driver pattern are traced into modules. The grouping starts with the technical solution with the highest score and then search for other TS with the same driver patterns or as close as. Up to this point each single function carrier has been considered to be a separate module, since the project group don’t want to risk getting a pile of function carriers in the modular system; grouping them accordingly to the MIM analysis helps prevent this. The grouping in the MIM analysis serves to provide as few sub-assemblies as possible in the production. A pile of function carriers which aren’t grouped risks to have a production setting which is too clustered with technical solutions due to; too many functions represented as sub-assemblies or modules.

Example of the vacuum cleaner above; The Housing, Grip and Cover seem to have the same modular driver pattern (Styling) hence it would be evident to place them in a single module.
4.2.5 Evaluate the Concepts by Testing the Interfaces In-Between the Modules-MFD
Step 4

In the fourth step of MFD an evaluation is made of the modular concepts interfaces and how appropriate they are for the production. The type of interfaces between the modules is important for the final product portfolio flexibility within the product offering. The interfaces come in two basic types, geometrical interfaces and energy interfaces (9).

The geometrical interfaces specify the boundaries of how the different modules are attached in geometrical aspects, e.g. the distance between them in an interface and the number of holes connecting them. An example is the geometrical definition of a Volvo BM attachment bracket. Energy interfaces exists for media transmitting of force, torque electricity etc. An example of an energy interface is the interface within an engine clutch or a connection in a computer monitoring system.

The geometrical and energy interfaces are being evaluated in a matrix where the modules are entered in an order of assembly and the interrelations between the modules are marked as G or E, see Figure 4-7. The arrows in the connection matrix’s point to two different kinds of preferable interface principles based on assembly of the product, the hamburger assembly and base part assembly. The two different types of assembly principles differs in the way that either the products reach final assembly in the same way an hamburger is assembled with a definite order of the process, or the product reach finalization from an assembly process revolving different base parts which make the final product complete and thus may be sub assembled to a greater extent than an hamburger assembly. Modular products thus either is sought to be assembled in sub-assemblies reaching a complete final product through a specific main assembly line, or by base assemblies which make up the complete product. Base assemblies may to a greater extent be simultaneously assembled, but to some extent not be tested in the same way as a hamburger assembly’s integrate parts. Connections outside these preferred principles should be avoided or be improved and changed (9). This chart also gives an indication of the possibilities of setting up the future modular factories to work as smoothly as possible.

Figure 4-7 Evaluation of interface complexity (26)
If each module is simultaneously assembled with the others in order to be delivered to the main assembly line, the ideal value for the assembly lead time can be calculated. The lead time of assembly is calculated as follow:

\[
Lead\ Time\ (L) = \frac{N_p T_{\text{norm}}}{N_m} + T_{\text{test}} + (N_m - 1) T_{\text{int}}
\]

Where:

- \(N_p\) = Number of parts in complete product.
- \(N_m\) = Number of modules in one average product variant.
- \(T_{\text{norm}}\) = Average assembly time for one part. Common value: 10 sec.
- \(T_{\text{int}}\) = Average assembly time on final assembly line for interfaces between modules.
- \(T_{\text{test}}\) = Average time for functional testing of modules.

The equation has a theoretical minimum value that can be calculated as:

\[
\frac{dL}{dN_m} = \frac{N_p T_{\text{norm}}}{(N_m)^2} + T_{\text{int}} \text{ which is 0 when } N_m = \sqrt{\frac{N_p T_{\text{norm}}}{T_{\text{int}}}}
\]

In an assembly point of view the average final assembly operation between modules should vary between \(T_{\text{norm}} \leq T_{\text{int}} \leq 5 \times T_{\text{norm}}\).

In theory it is possible to shorten the lead times by further dividing the modules into sub-modules. However, the limit for this approach of sub dividing is reached when the work content in the modules gets too small. The assembly process doesn’t justify this approach of sub dividing but might be justified from other perspectives in modular design (9). With a sub division more interfaces are appearing and in a modular perspective the number of interfaces are sought to be as few as possible. The interfaces must also be easy to specify and fixed over some years to achieve freedom between the development teams of the modules. This result in the smallest possible information flow between the design groups and shortens the time of development. The lead time in development decreases when it is possible to work parallel and according to the case studies of Erixon, the decrease of development lead times ranged from 30-60% with a median of 45%. The simplicity of the interfaces between the modules is preferable and is designed without causing an increase of complexity in the architecture. The specifications of an interface are made by giving:

- Form
- Number of contact surfaces and attachments
- Material flow
- Number of energy connection points
- Fixation principles
- Signals
For each interface a certain amount of information is needed, thus; low complexity is related to ease to specify in this scenario. Making the interfaces as simplistic as possible, e.g. no handling difficulties and no obstructed insertion operations exist; the development and assembly processes become more effective leading to reduced lead times, costs and increased quality and value on the possibility to work in parallel design projects. This value is referred to as Interface Complexity and is calculated as follow:

\[
\text{Interface Complexity} = \frac{\sum_{i=1}^{N_m-1} T_{BDI_i}}{S}
\]

Where:

- \(N_m\) = Number of modules in one product variant
- \(T_{BDI_i}\) = Assembly time for one interface, interface \(i\).
- \(S\) = Ideal operation time, 3 seconds.

When the Interface Complexity becomes low, the probability of successful parallel development and small needs of information flows between design projects increases. The ideal state is to minimize the number of contact surfaces between the modules as it decreases the risk of affecting other modules negatively when developing (9).

4.2.6 Improvement of Modules using MIM and a DFX approach - MFD Step 5

The last step of Modular Function Deployment includes improving the separate modules using Design For X method. The different modular drivers come into account since the mechanics of this improvement is set to target a specific goal (goal = X). Design For Service methods may be used for the modules structured for Services or maintenance as an example.

The improvement in the MFD process consist of specifying specific data about the modules and which department that’s in charge of the module, technical solutions in the module and which specific modular drivers that’s involved. Design for X is a generic name for a design processes that target different development problems of engineering; production, operations, service or lifecycle etc.

A strong aspect of the matrix approach to a modularization problem is the tremendous advantage of the informational input since it presents opportunities to extend the analysis further. There are multiple tools with a matrix approach; QFD, MFD, Design for Manufacturing, Design for Assembly, Design for Service.

According to Erixon the design of each module has a great impact on the product cost. The Design for Manufacture and Assembly is therefore important to pursue for each module design. The product cost includes capital costs, tools, fixtures etc. and the size of the costs depends on the number of parts and modules as well as the assortment complexity in the product flora. To control the complexity the reuse of modules and processes is suggested. It is possible to calculate the Assortment complexity with the calculation:
Where:
\( \text{Nm} \) = Number of modules in one average product variant.
\( \text{N}_{\text{mtot}} \) = Total number of module variants needed to build up the product range.
\( \text{Nc} \) = Number of contact surfaces between modules in one product.

The number of contact surfaces is calculated based on the total assembly operation time for the interfaces and divided with the ideal assembly operation time of 3 (28). The number of contact surfaces is calculated according to:

\[
N_c = \sum_{i=1}^{N_m-1} \frac{T_{\text{int}}}{S}
\]

Where:
\( T_{\text{int}} \) = Expected assembly time in the interface i.
\( S \) = Ideal operation time, 3 seconds (9).

To visualise the capabilities of this last step consider the QFD process, it can be utilised to enable the voice of the customer to affect the product planning, production planning and manufacturing planning. A further extension of the HoQ involved in the MFD methodology is the QFD model, see Figure 4-8.
with the customer demands, but can also be used to set the different modules to function in production as good as possible, considering the two different “optimal” assembly assortments.

Value engineering seeks to increase the value for the customer by starting the development process through a need finding process of the stakeholders needs both internally and externally. Through research and applied examples of value engineering, evidence have been found to support the idea that the secure way of a company to become innovative and continuously growing is to give the company access to the needs of the customer on a value base (29). Each need has to be provided for and by the product in the most valuable way both for the customer and for the company. Simply because the need of a product usually outlives the want of a product.

The mechanics of the product based MFD analysis is similar to the QFD method, but seeks solutions to modularity by applying Östgren’s modular drivers, see section 4.2.4, to both the internal and external aspects of the product, and then later on use the QFD if the design team find it fitting. Via needs finding with customers and end users of the product, as well as with the internal stakeholders of the information flow around the mechanical product; a modularization of the product offering and information flow would be structured around customer values.

With value engineering, a solution to product modularity with the MFD process might solve problems shown within the matrix analysis of the iterative process. The different departments of the company seek different values from modularity, and the customer needs and end user need might not be aligned. The modularization project within an organization thus must take into account the network of information and values within the company and outside the company. The network of different information’s is crucial to capture if the needs findings of the MFD process if it is to be correctly conducted and aligned with value engineering.

4.3 The Value Network and Information Transactions

An organization usually works as a role in a broad network of other roles, including customers, suppliers and other businesses. Internally there is also a network that is linking the individuals together in a web of informational flows which is referred to as value flows. A flow can both be a tangible value or an intangible value. In a multifaceted organization, the network tends to become vast and complex and includes regional divisions that connect each other on a global scale. For the company, a mapping of the value network helps provide an understanding about a specific situation; e.g. customer relationship to the internal business network, the specific roles in a development process and connections between teams in a corporation. In a modular development the need finding process of development is important as it seeks to ensure value creation for the stakeholders’ desires.
It is important to first understand the structural design of an organizational network and how one should look at it. Value networks and organizational networks can be described as a dynamic living system, which is predictable in a certain degree but not in the specifics. According to Verna Allee, modeling a business network through the perspective of a living system requires being able to; identify the pattern of the organization as an organization, describe the structure of the organization and unveil the most critical processes or exchanges of the system (30).

When people talk about flows in the network, they usually imply tangible exchanges e.g. product transitions, revenue transitions and service provision, between the roles. A complex network has intelligence, which means they engage in cognitive trades such as knowledge and informational trades, known as intangible exchanges, between the roles in the network, to both learn and to allow good decision making. Being one of the most important aspects when designing the network for module development and production, intangible flows are necessary to include when looking at new process configurations of the organization (7). In the development of modular product it is essential to understand all the needs before designing the modular infrastructure of the architecture and interfaces. Thus the knowledge trades of the current and future needs in the products and services must be included in the network flows to the developers of the modules.

<table>
<thead>
<tr>
<th>Tangible Assets</th>
<th>Intangible Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods</td>
<td>Strategic information</td>
</tr>
<tr>
<td>Services</td>
<td>Planning knowledge</td>
</tr>
<tr>
<td>Revenue</td>
<td>Process knowledge</td>
</tr>
<tr>
<td>Contracts</td>
<td>Technical know-how</td>
</tr>
<tr>
<td>Knowledge products</td>
<td>Collaborative design work</td>
</tr>
<tr>
<td>with immediate return</td>
<td>Patents</td>
</tr>
</tbody>
</table>

Table 4-4 Tangible and intangible assets of a company

As seen in Table 4-4, all tangible assets includes some physical substance while intangible assets don’t, making them much harder to evaluate the value of. Tangible assets are usually physical effects that can be measured directly and the effect on the company is more direct than with intangible assets, which usually leads to indirect effects on the company; e.g. a knowledge enhancement of the developers can generate tangible value in five years. Nevertheless, it is important to see the opportunities in intangible assets as they can generate a great amount of opportunities and strengths for a company.
A basic value network process and analysis is used to map out the business processes between roles in the network and to discover dead-ends of information or weaknesses in the network. This is usually done by building the network with tangible and intangible flows, see Figure 4-9. However, in a complex organizational network setting it is important to set the boundaries before studying the network; how deep you want to go or how close on a specific role you want to study.

Today’s businesses work with other businesses within business webs. Hierarchical organization networks are obsolete and associates cooperating today are scattered all over the world while working in the same project groups (30).

In this thesis project the constrains are set to look at the organization from a modular business perspective, meaning that the objective are to look at what value flows are important when configuring the network for a modular product design. Compared to an integrated design, the collaboration and knowledge exchanges between the divisions in a modular design become more significant. This is due to the fact that modular design needs a clear ownership and responsibility over the modules to ensure duplication of processes doesn’t occur (7). Intangible transfers between parties when developing, ordering, marketing, maintaining etc. thus becomes crucial and are of great value for the organization.

Even though modularity requires a broader range of knowledge of each module across the divisions, when enhancing and developing a specific module without the need to affect other modules of the product, developing becomes easier (31). Instead of, in some cases of traditional developing, having feedback and reports of error going to multiple different
product types. The implementation of a module over multiple products implies that you get one receiver instead.

In the organizational system the introduction of modules put a lot of demand both on the internal sources as well as on the external. The organization must decide whether they want to add the costs of external manufacturing of the modules or keep the manufacturing in house. The system costs mean the overall cost of supporting the assembly systems and depend on the share of purchased modules. These costs are influenced by different aspects, see below.

<table>
<thead>
<tr>
<th>Type of costs</th>
<th>Influenced by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase</td>
<td>Number of vendors</td>
</tr>
<tr>
<td></td>
<td>Number of different parts</td>
</tr>
<tr>
<td>Production planning</td>
<td>Complexity</td>
</tr>
<tr>
<td></td>
<td>Number of parts</td>
</tr>
<tr>
<td>Quality control</td>
<td>Complexity</td>
</tr>
<tr>
<td></td>
<td>Number of parts</td>
</tr>
<tr>
<td>Production engineering</td>
<td>Number of modules</td>
</tr>
<tr>
<td></td>
<td>Complexity</td>
</tr>
<tr>
<td>Logistics</td>
<td>Number of vendors</td>
</tr>
<tr>
<td></td>
<td>Number of parts</td>
</tr>
<tr>
<td></td>
<td>Number of different parts</td>
</tr>
</tbody>
</table>

Table 4-5 System costs and influences on the costs

The above discussion cannot be solely used for the assessment as there are other factors that control whether an external production should be utilized for the modules or not.

- Are there strategic reasons for keeping production in house?
- According to the product plan, do we have capacity to produce the module?
- Are there any qualified companies for producing the module?

As Erixon states there is revenue to be saved with the use of external production sources. The higher the share of modules the lower the system costs (9).

4.3.1 Introducing Modularity into the Organizational Network

The ever increasing competition in today’s physical product markets has forced the companies to attract the customers in alternative ways, which ultimately cuts the costs, decreases delivery times and increases the quality of the physical products. This has been done by introducing software and service solutions into the manufactured products, increasing the relationship between the customer and the company, leading to an improved brand loyalty of the customer (32). This could serve as a supplement to the qualitative products, increasing the customer loyalty while gaining valuable information and knowledge of their products when the customers are using the machines.
The introduction of modularity in a company will affect the physical products as well as the information flows inside the network. A reduction of components in manufacturing, the need of rules in the network to solve modular development complications and the need of a broad skill base when designing are some aspects that reflect a modular business strategy. Modularity requires an organization that can use effective cross-unit teamwork to provide every stakeholder with a solution that benefits their needs. Solutions will occur that won't always benefit every stakeholders needs; both from shifting requirements and impossible solutions combos between products ranges (7).

In a modular organization network it is much harder to push through with new ideas since more products, hence stakeholders get affected by the changes made. The processes must thus be well-defined for the employees and it is a necessity for the organization to keep control of the changes made on the modules since it can affect the whole organization. The need of a strong rule set is thus evident and requires the individuals in the company to follow the structure of the businesses to ensure that each stakeholder has the same understanding about the processes and their purpose.

There are studies on how a company should transaction from integral design to modular design in their products (7) (9) but less on how a company contain the strategy of modular development, which the analysis of this thesis are aimed to answer. In the process of introducing modular development the company must assembly all stakeholders to determine feasible design alternates. The outcome of the discussion between the departments i.e. product development, manufacturing, project management and marketing, is a decision on design architecture of the products. This design should reflect the needs of the stakeholders and technical considerations of the products which are studied (7).

As observed in the literature the company must have an effective need finding process in order to develop for modularity but must weigh the needs against the technical requirements. Hence there will be products that benefit from the modular implementation while other products wont, making them exposed to a higher cost. This is a challenge in the business environment since the new processes will have to have a cross-functional collaboration between product divisions that previously didn't exist and also requires collaboration between the teams (33).

The cross-function collaboration is a result of the requirements of modular development and puts a lot of new requirements on the organization network that previously wasn't as essential as it becomes in a modular environment. Since modular environment is a way of decreasing costs and connecting functions in multiple products into similar solutions, the need of cross-product teamwork is essential. Sharon Mickan and Sylvia Rodger have studied the characteristics of effective teamwork and draw the conclusions that there are seven characteristics in the organizational structure which are requirements for an optimal teamwork, see Table 4-6 for all characteristics of an effective teamwork.
4.3.2 Configuring a Profitable Informational Network

Smart business design is one of the essences of successful organizations today and recently the design of organizational networks has evolved by the emergence of IT. Successful organizations today are gathering huge amount of information from their customers, integrating them into their business, are more agile, have a broad scale of knowledge thorough their network and move positions faster than others. These organizations also provide solutions for their customers whom others don’t, which helps them gain advantage over their competitors on the market and helps to increase the value for the customers.

The network should manage to accomplish many diverse tasks, from ordering to problem-solving while keeping the customers interested in the business and providing new innovative solutions for the next generation of products. Looking at some of the e-businesses that are emerging, who provide platforms and enough information about the products for their customers to tailor their orders to fit their needs, share information about the products to the company and other customers and to have control over the payments (34). This contributes to more responsibilities for the customer and in some cases a sense of individuality and participation. Successful computer retailers are providing services for customers to build their own computers, using modular parts that are developed from different manufacturers. Each module are reviewed by customers, hence eases the development for the part providers that can study the module on its own without affecting other modular parts in the computer.

There are also benefits of configuring the network in terms of sustainability; reducing the number of errors in the system and products with a good network decreases waste of both information and materials. Information can flow from the divisions of a company as well as between the products themselves making a good service system to the operators aware of errors before they happen but also about the products emissions and efficiency (35). Processes that are well-configured provide the organization with solutions that meet the worker’s needs when designing for modularity and creates value for the company, hence increasing the value for the users.

When an organization has a well-configured network they learn to innovate on a different level but as they generate new ideas the application of new innovations is also an undertaking sometimes forgotten. Hansen and Birkinshaw have presented an innovation process in businesses that involves idea generation, idea development and transmission of developed concepts. During the processes, the managers must perform six critical tasks; internal-, cross-unit-, and external sourcing, development and diffusion of the idea over the organization. The process is called the innovation value chain and aims to help the organization to generate innovations and implement them into the company. In the process of applying the process into the organization, executors are asked to take an end-to-end view with the purpose to find the weakest link of the organizations current configuration in the process (36).
4.3.3 Characteristics of an Effective Teamwork

In all types of organization the key to success is spelled “teamwork” and is based on a number of key elements of achieving it. There are three basic sublines of achieving an effective teamwork and these are:

- Organizational structure
  - The organization must provide their members with a structure that is beneficial of achieving a good teamwork.
- Team processes
  - Each team must be good in handling different situations and these processes describe what the team must manage.
- Individual contribution
  - A common expression usually is “a team is never better than its weakest link”, and it can describe the last sub line of effective teamwork.

These sublines includes a number of characteristics of which describes effective teamwork, see Table 4-6.

<table>
<thead>
<tr>
<th>Organizational Structure</th>
<th>Team Process</th>
<th>Individual Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Purpose</td>
<td>Coordination</td>
<td>Self-Knowledge</td>
</tr>
<tr>
<td>Appropriate Culture</td>
<td>Communication</td>
<td>Trust</td>
</tr>
<tr>
<td>Specified Tasks</td>
<td>Cohesion</td>
<td>Commitment</td>
</tr>
<tr>
<td>Distinct Roles</td>
<td>Decision Making</td>
<td>Flexibility</td>
</tr>
<tr>
<td>Suitable Leadership</td>
<td>Conflict Management</td>
<td></td>
</tr>
<tr>
<td>Relevant Members</td>
<td>Social Relationships</td>
<td></td>
</tr>
<tr>
<td>Adequate Resources</td>
<td>Performance Feedback</td>
<td></td>
</tr>
</tbody>
</table>

Table 4-6 Characteristics of effective teamwork (33)

4.4 Sustainability

From the Brundtland Commission Report one can draw the definition of sustainability to be defined as; “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (37). Other groups as IUCN, UNEP and WWF describe sustainability to be “improving the quality of human life while living within the carrying capacity of supporting ecosystems” (38). Hence the combination of environmental, social and economic aspects are gravely important, and thus the opportunity of sustainability offers companies business opportunities to improve the lives of the inhabitants in different market segments (39) (40). As a company strive to excel in selling their products, the future of the Earth is important both since they sell products that help to build societies but also because their business need customers who buy their artefacts, the future wellbeing of the world is just as important to the company as to the individual and the legacy.
4.4.1 Opportunities in Modularity towards a Sustainable Future

Usually when sustainability is discussed there are topics on the debate such as emission cuts and regulating the used materials within or around a product or usage of a product. Modularity fits within this discussion since each module needs to be used and produced, thus the traceability of the environmental impact of each functionality in the product becomes easier to trace and sum up, therefore easier to prefect when it comes to emission and environmental footprint. When each module is produced and developed, sustainability can be an inherited focus of the work and used materials and each function’s emissions can be lowered to a set goal or predetermined baseline.

If sustainability is a given goal of any development or production the operations get the benefit that streamlining and lean operations are not only giving cost rewards but as well as reaching goals of the sustainability. Within Volvo CE's Core value there is a high brand value of environmental care and hence sustainability already has a given place within VCE. Modularity is merely the springboard to make it happen since it enables solid actions of improvement to act directly upon the product and surrounding services. Modularity enables sustainability improvements, since the modular product provides the opportunity to change logistics and production of the company, and the setting of each product. The operations of the company and product hence can be set to be as sustainable as possible for the future and nature.

4.4.2 Product-Service Systems - Functional Oriented Business Models

Developed in academia, a function-oriented business model is a way of restructuring a company strategy to deliver a Product Service System as a part of their deliverable as a company. The function oriented model is aimed at providing sustainability for both consumption and production and sales towards customer and company. In the business of Volvo CE the transitioning toward a total solution is a strategy of providing the user with solutions that suites their every need while limiting the environmental impact the company ejects.

A function oriented business model is called a Product Service System. It is aimed to let a company provide both services and products, compared to a traditional company structure which usually is aimed and set to provide tangible products. “A marketable set of products and services capable of jointly fulfilling a user's needs” (41). A business that utilize the strategy of a Product Service Systems are usually an organization that provides products which allow for a lot of informational entry towards the function of the product in order to improve the usage and cost for the company as well as for the customer.

The shift towards a functional oriented business model were initially motivated by the need of realizing and coping with the changing market requirements, and the realization that services in combination with products provided higher benefits and ROI for a company than solely relying on providing tangible products (42). Companies lately have faced shrinking markets and increased commoditization of products which has set the path for the modern consumption. In the modern industrial era consumers not solely demands products but also
require services to support their products, companies thus have realized service provision as a new path towards market growth and enhancing market share (43) (44).

Product Service System result in the decrease of material consumption both within and outside a company, hence a PSS is usually traced towards and connected to a company’s environmental strategy. Some researches even acknowledge it necessary a PSS strategy to include improved environmental impact in the strategy and business model of shifting towards services. Oksana Mont has highlighted the fact that PSS results in a lower environmental impact and proclaims that PSS is "a system of products, services, supporting networks, and infrastructure that is designed to be: competitive, satisfy customers’ need, and have a lower environmental impact than traditional business models" (45). The definition hence is elaborated to be a pre designed system of products that is combined with services, supporting systems and infrastructures as well as necessary networks that dematerializes the solution to the consumers preferences and needs. Product service systems also in some cases are considered to be self-learning systems, since the goal is to continuous improve in order to cope with the changing customer desire and market changes; e.g. changing diagnosis of fuel consumption when operating a machine depending on workload, speed etc. can generate an average consumption per operator.

Researchers of PSS assess that a functional oriented business model systematically may improve the environmental impact by what is termed as the factor 4 i.e. an improvement of the operation of the company by a factor of four or more, by enabling new and innovative ways of transforming the company deliverable. Due to that a PSS is structured around satisfying the customer’s desires, while improving the environmental impacts (46).

Van Halen claims that the knowledge from functional business models may enable policies to be formulated by governments with respect to both sustainable production of companies and sustainable consumption patterns of citizens. According to Van Halen this enables governments and companies to discover new guidelines for business growth, innovation, change of technology and businesses to enhance renewal and sustainability for the future (39).

4.4.2.1 The Organizational Network, PSS and Sustainability

When studying sustainability in an organizational environment the reduction of waste and lean production is usually included. Lean was developed to lower waste in the manufacturing but has later been applied to both internal and external services of the organization.

According to Walton, waste is often referred as Muda in Japanese context and there are two types of Muda (31).

- Muda I is found in activities that add no value to the customer, but are necessary to deliver the product.
- Muda II is found in activities that don’t create value and which can be eliminated immediately.

In a service environment waste could include information taking unwanted paths between
roles that aren’t in need of the information. The idea of configuring the network is to provide the right roles with the right information at the right time, more commonly known from the manufacturing planning philosophy Just-In-Time.

The organizations are becoming better and better with interacting with the products and users on a closer level but a company to beat their competitors, it is important to understand the needs of the customers and the organizational network in order to deal with product and user related errors that results in broken sustainable principles (47). Effective configured service solutions can provide the organization and customers with information and knowledge which could decrease the environmental and social harmful impacts.

An analysis of the organizational network and studying of the value flows from the customers can provide results that benefit the company to introduce PSS solutions into the organization, which might increase the customer loyalty as well as decreasing the environmental impacts (39). With the introduction of modularity in the business, the complexity of the products will be hidden from reducing the number of specific parts and introducing a shared architecture, hence making product- and use-oriented service solutions more beneficial for a company and its stakeholders, see section 4.4.2.2.

With the replacement of hard products with services, fewer materials are used and thereby decreasing the impact on the environment but it also eases the work for a business and their customers because of the customization ability of services. Services should be designed in a way to suite a wide range of customers but including modularity to services, it should fit the whole range of customers. The combination of different service modules makes it possible for the customers to combine functions that suite their every need (6). Therefore, also the result-oriented PSS types, where hard products are replaced with service solutions, are a beneficial solution for sustainability development.

4.4.2.2 Various Product Service Systems

PSS have been in focus of research for several years, and since markets, product structures and customer desires are gravely different there have been issues raised in the terminology since business models of companies rarely are comparable as a generic structure, and thus the structure of the PSS is different for each company. Since the traditional services are considered a product in a PSS and although the service need a tangible product to support the delivery of the function, each company must design their PSS to suit their goals as well as the customer desirable function of the service.

Research revolving PSS have focused towards including and combining tangible and intangible products to provide for the customer needs. Researchers has shown that manufacturing companies are more willing to produce results, rather than solely tangible products as artefacts, and consumers are more willing to consume such results in form of a functional deliverable (46). These ideas have defined three different sections of Product Service systems, with 8 different under-categorized types of PSS, see Figure 4-10.
The process of introducing services into manufacturing companies has emerged faster with the development of the information and communication technology (ICT), spreading from pure product oriented to use oriented to result oriented services.

Product Oriented PSS

In this system the ownership of the tangible product is transferred to the consumer, but additional services are provided; e.g. maintenance contracts or education.

Use Oriented PSS

In this system the ownership of the tangible product is retained by the service provider, who sells the functions of the product, via modified distribution and payment systems; e.g. sharing, pooling, and leasing.

Result Oriented PSS

In this system the products are replaced by services; e.g. voicemail replacing answering machines.

Some researchers criticize this idea since it fails to capture the complexity of implementing a PSS into practise. Hence an alternative typology of PSS have been developed deriving from two characteristic features within the PSS (49). The first feature is explained as the performance orientation of the revenue and can be designed as:

- Input-based
- Availability-based
- Usage-based
  or
- Performance-based

These features can be further subdivided into three subtypes:
• Solution oriented PSS
  (E.g. selling a solution of productivity instead of selling just construction equipment)
• Effect oriented PSS
  (E.g. selling a promised amount of production efficiency on a working site)
• Demand-fulfilment oriented PSS
  (E.g. providing a total solution in order to satisfy all stakeholders’ needs and requirements on a working site)

Considering the second feature, which is explained as the amount of integration between the intangible service products and the tangible product, the PSS can be designed as:

• Segregated
• Semi-integrated
  and
• Integrated

Revolving around to which extent the tangible and intangible products (e.g. maintenance service, spare parts) are combined to a single offering from the company.

4.4.2.3 Product Service Systems in Case Studies of the Industry

Case studies have been made on companies that have implemented a function oriented business model as a solution towards increasing revenue as well as improving the environmental impact and innovation within the company and the products. Following are some examples on case studies available to assess in order to find the opportunities with Product Service Systems.

4.4.2.3.1 Rolls Royce – Power by the Hour

The company Rolls Royce offer an opportunity to sign a contract which ensures the cost of both running and maintaining the product of jet engine from Rolls Royce to be fixed or predicted in order to ensure a better economy for the customer and better control over the life cycle of their engine. The customer pays a price for the amount of time the engine has been flown. The maintenance contract has changed from the start of the project, to ensure a quality and cost over a 5 to 10 year period, to ensure the entire life cycle. Thus the risk of ownership for the customer is lowered (50). Today over 70 % of Rolls Royce revenue comes from the total care sector and the additional improvements in value according Rolls Royce beside revenue are (51);

• Low risk, fixed cost engine maintenance - The comprehensive suite of engine management services available under CorporateCare provides predictable costs over the life of the agreement and covers all aspects of engine maintenance and management
• **Reduced management burden** - CorporateCare enables you to focus on your priorities, because Rolls-Royce provides a full suite of Engine Management Services

• **Enhanced aircraft resale value** - CorporateCare is transferable with the aircraft and therefore increases its residual value

• **Increased aircraft availability** - A lease engine is included in the plan when your engine is in the shop

• **Reduced capital investment** - You need fewer spare parts and tools

• **24/7** - Benefit from a world-wide network of support focused on the needs of corporate jet operators. Our network is always there for you, 24 hours a day and 365 days a year.

### 4.4.2.3.2 Volvo Aero

As a producer of jet engines, Volvo Aero has implemented a similar kind of PSS structure as Rolls Royce. One of the differences from Rolls Royce setups are that Volvo Aero are prepared to engage in taking responsibility for some of the customers cost for the tangible product, in essence making Volvo Aero share responsibility and ownership for the Jet engine while it's utilized by the customer in exchange for revenue of the usage. This lowers the initial revenue of the sales of the tangible product for Volvo Aero, but enhances the operational revenue of the company. The shift has been measured to be lowered revenue in sales by a 16.5% but an increase in operational income by 17.5%. Over time the lifecycle of each tangible product will bring more revenue towards the company than if Volvo Aero wasn’t involved in the ownership of the product. A derivative from this system is that fewer products will be produce since each product is running at its optimum and a stock of estimated sales is not needed, thus lowering the environmental impact of material, work and energy of the company (50).

![Figure 4-11 Revenue and operational income change of Volvo Aero 2010-2011 (50)](image)
4.4.2.3.3 **Man Trucks – Total Cost Ownership and Fleet Management**

Today, Man trucks offer the ability for customers to buy service and leasing contracts on their products. The ability for the customer to buy a product with the knowledge on the cost per mileage, have enabled the company to find new revenue streams that previously weren’t available. The split between the tangible sales and the service contracts today is 70% as compared to 30%, but when looking at profitability, the split is the opposite. Man trucks decided to shift their business model due to the motivation to enhance the customer satisfaction. Since the new business model require the company to change in order to ensure customer satisfaction, otherwise the contracts of leasing and services is not sign in long term y the customer. In order to tackle the dissatisfaction of the dealer’s new role as solely service providers, Man Trucks educated them in the new business case of providing PSS solutions to their customers and introduced a so-called Dealer Satisfaction Index (DSI) to evaluate and improve the relationship between them. This enabled a smooth the transaction from providing tangible products and service to solely providing services (50).

4.4.2.3.4 **Major Challenges with Implementing PSS According to Case studies**

In each case scenario there were implications from utilizing PSS in the business. Two of the major challenges from the implementation of a function oriented business model in the case studies above are presented in this section.

**Design and Development of the Products**

In order to successfully deliver products to a PSS it is important the engineers understand; when assessing a new technology or implementing a new design, the revenue from the system needs a hibernation time. Each product generate revenue first after the contract have been effectively engaged, hence if a new technology is developed in order to be implemented to the market in 15 years, the resulting revenue is first returning to the company in an additional 15 years, since the revenue is generated by servicing and creating value for the customer in the entire life cycle (50).

**Changing the Mind-Set of the Customer and Retailers**

The customer and retailers needs to change their mind-set from a onetime purchase relationship to a total cost of ownership (TCO) understanding. Since the product receive a longer lifespan the relationship between the retailers, customer and product gains much more weight in value for the producer. Relationships and comprehension of the situation of each customer hence is an essence to capture the revenue and value in the business model. The company need customer needs, as customers require satisfaction (50).
5 Analysis - The Implications and Opportunities with Designing Modularity

VCE is currently providing over 200 unique products and numerous services which make their business complex and difficult to structure for a new business model and development process. New customer needs, legislation rules, society changes etc., pave the way for an expensive development of both products and services at Volvo CE. Each product and process change at Volvo CE needs a purpose before applying it to the new business, to decrease the risk of a future breakdown.

The aim of this chapter is to provide the reader with an understanding of the difficulties and opportunities when designing for modularity in the case of a multi-faceted business as VCE and the opportunity and difficulties with implementing a Product Service System business model. Each product and process change at Volvo CE needs a purpose before applying it to the new business, to decrease the risk of a future breakdown. In the current situation VCE is providing services and softer PSS under the name of Soft Products. In the future VCE is looking towards implementing a full PSS under the name of Total Solution in order to provide the maximum value to the customer. Modularity enables an implementation of a total solution. The results are based on interviews, workshops and literate reviews.

5.1 The Basis for the Analysis

The achievement of this analysis derives from a study of certain documents within VCE which are used as the support for decisions within projects and development. Changes in the information of the documents from transitions between different departments and hierarchies within the company led to difficulties related to an outlook of modularity in the future. The documents were by obvious reasons condensed through the process of travelling within VCE. Since the decisions of each project are performed at different hierarchical levels, it is crucial that the management are capable to absorb the most crucial information. The changes in the documents were studied with respect to date and author, and we interviewed the people involved in managing and using the documents along the process. The different documents were: product flashes – the future plan for changes in products, BOD, GPCM, CBC, Requests for Feasibility studies, Equipment summaries for WL such as; options lists, Global Delivery Lists for WL, and different Cost Data from VCE. The employees interviewed along the process where from the different departments of; Product Planning, Global Marketing, Technology, Production and After Market.
5.2 SWOT Summarize of Modularization in the Business of VCE

This is a summary of the complete SWOT-analysis\(^1\) found in Appendix 1: Necessary Actions moving towards a Modularized Design - SWOT Summarisation of Analysis and includes the strongest bullet points. The findings in the analysis are based on the results from the SWOT.

**Strengths**

- Strong tangible and intangible assets in Volvo CE;
  - Experienced company with a broad knowledge in the markets
- VCE have production facilities in most continents, established markets in all continents and thousands of employees in fields of development, management and production
  - Broad understanding, local understanding of the market segments
- Volvo CE already has an understanding of the requirement of including all stakeholder needs in the development process of modularity
- A broad understanding of requirements when developing modular products in a Volvo CE premium fashion
- Volvo CE has a good cross functionality between the divisions
- All information is somewhat traceable and exists in the concern

**Weaknesses**

- VCE lacks a shared language in their business;
  - No shared documentation structure
  - Differentiated software systems
  - No coherent understanding about modularity
- Volvo CE lacks the network design to easily trace some of the information
- Some negative mentality concerning modularity of the developers and engineers
- The current developing projects requires periodic need finding processes
  - In modular development this can require a complex process which is necessary on a global scale and it is time consuming and might result in an inadequate need collection
- The employees filtering the information mentioned above must be fully aware of how the process of modularisation works
  - There is currently no clear documentation structure standards at Volvo

**Opportunities**

- The new business strategy of transitioning towards modular development can result in a shared language across the organization

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\(^1\) SWOT – Strengths, Weaknesses, Opportunities, Threats in the organization.
• Decreases the accumulation of articles and parts due to a common architecture and set of rules which controls the development of new unique solutions
• New market and development opportunities due to modularity; PSS, total solution, integrated systems, regional projects
• Shared technology over the entire organization
• Clearer informational flows bring more value towards the development teams
  o Defined process designs internally eases the detective work for engineers
• The network will embrace unity and will be easier for the individuals at VCE
• A shared computer environment may evolve and turn into something which will fit into the machines and work like an open source environment in the future
• Innovations from other companies in the network will be easier to implement
• Increased brand value and loyalty- due to improved and faster serviceability and maintainability from the modular design
• Easier to supply markets - retailers and customers - with local production, it is both a faster and more sustainable strategy at Volvo
• Traceability of information takes a more central position when the emerging towards modular development
• With PSS and modularity VCE can provide both sales and rental services
• Secondary life value can be enhanced with updated modularized products and PSS solutions can make use of old modules from secondary/after life products.
• Errors which aren’t detected in the development process will be faster discovered from customers operating the machines
• Modularity benefit a shared regional production;
  o Ensure a closer connection with the customer; emotional and geographical
  o VCE could buy supplies and sell their products in the same currency
  o VCE would have a broader supply base
  o Same tools can be used in the entire organization
  o Shorter logistic lead times

**Threats**

• Implications and misunderstandings in the business when changing the processes
  o If stakeholders don't understand the process changes and the necessities in the process during education, the system will be damaged
• Unsustainable need finding if the modular development fails to apply a cross product view of the needs
• It is hard to create a functioning architecture on a global scale which are sustained in the future
• The company could suffer costly adjustment if the interfaces are not configured for a global market;
  o Allows for modular development on a regional level with a defined architecture
• Transition to a shared language might result in translation mistakes
• Modularisation may expose more products for failure when developing a module, due to shared functionality when using a module that do not fully fit the environment
• Secondary life value get damaged if the customized modular product isn’t able to be reconfigured
• Dealers don’t accept the PSS business model; The business model isn’t functioning correctly as the dealers have a role in it

5.3 Issues with the MFD process in VCE’s scenario

Although Modular Function Deployment has been proved as a method in previous industry segments, there are some issues towards the scenario that VCE is facing. In a holistic analysis of the MFD methodology engineers, managers and developers can assume some facts about the MFD process.

• The customer needs analysis must be conducted correctly to solve a modularization problem
• The modular drivers needs to be manageable and resonate with the project group and developers, in essence the drivers needs to be understood by the team
• The drivers need to give the company value as, increased market share or ROI
• A necessity is the capability to speak a common language in the project group

This puts a great pressure towards the managers and engineers that seek to conduct a proper modularization of the product and production. Through interviews and research in the ongoing modularization project and architecture work within VCE the authors found that the attitude towards the process is not always positive due to the complications with changing the developing process of a product range and they feel that there will be less opportunity for being creative which would degrade their ability of skilled engineers. There is also a differentiate understanding to what modularity is or are aimed to be by the managers contra developers.

If any correct modularization is to be conducted there is a strong need for both managers with the holistic view on change and engineers with a keen eye for details in R&D and construction. It is important that all the involved people within the development of modularity have a shared common base of knowledge about the process and the topic of customer need and how to conduct a need based development process. Otherwise the language within the project groups is flawed and constrains the advancement of the modular project.

The importance of a genuine and shared language and understanding of customer requirement is necessary because of the structure of the process. Since the essence of the process is to access the requirements of different customers, internal and external, it puts a responsibility towards the developers conducting the analysis to be open minded and recipient towards any opinion of a stakeholder. The organization of VCE is currently operating at all five continents
around the world, making the cultural barriers one of the aspects of communicative implications. Stakeholders at different locations might have different perspectives on certain things, making the modular development process much more complex compared to a regional similar business.

Another issue at VCE is the multiple IT systems existing in the organization. Transferring new information about new configurations of the modules requires the company to use identical IT systems to minimize overhead costs of translating new information to new system; e.g. CAD files created in one CAD-software might not be functional in the next software. These are issues that are usually expensive to implement and also requires a learning process before the employees are familiar with the system, but are a requirement for the new business model to work optimal. If unity is not carried out, the global implementation and further development of modular design at VCE becomes even harder to succeed with. There is also a need for a global scale of teamwork among all divisions to ensure Volvo CE can continue to deliver high qualitative machineries to their customers without degrading the ability to develop. If anything, the ability to develop should become safer, less costly and easier for the organization as a whole.

As the current development is conducted within Volvo CE, there is key knowledge considered to be held within certain people in the projects, because of the origin of the machinery knowledge and processes within Volvo CE. The involved engineers with experience in many years of development of the business and products have the responsibility to often make fast and secure decisions about the direction of the company and projects. This forces them to make fast decisions about things that sometimes is not fully investigated or understood since the process relies on their knowledge about the products to be true.

The knowledge within this senior engineering body is not to be neglected or overlooked in the MFD process but a caution is to be held towards any judgments within the need finding process, as it might constrain or fully destroy the ability of the analysis to create any value free from bias.

Although there are other aspects of the process where opinions gravely matter, the modular drivers for instance, is a body of the analysis which might crave for discussion depending on the scenario of the modularization. In the situation of mature products the generic modular drivers may be effective. But VCE’s situation with a diverging and complex product flora, the modularization may become too complex and big for the specific modular drivers and need something closer to a design mentality of the product before conducting the grinding work of a MFD process. This because the amount of work needed to conduct a modularization project on each specific product is too great. This puts even a greater deal of pressure on the designers and developers as a mentality is hard to monitor and measure with a tangible aspect. Since modular drivers are the crucial and valuable part of an internal modularization process and need to be manageable and understandable in order to bring value to the process of modularization; it is important that if VCE shift towards having modular drivers as a design mentality, rather than having them as a tangible goal - it is crucial that the mentality is
confirmed and understood in order to bring value for the company. Tangible goals are much easier to manage rather than confirming a good mentality towards a design problem.

5.3.1 Modular Drivers and Volvo’s Current Product and Service Situation

To maintain competitiveness VCE is currently combining products and services in better and new ways to satisfy the customer needs. This creates a highly challenging environment since it involves implementing new strategies, product structures and offers to the customer and company. To ensure that the customer value is created, Volvo documents to some extent their needs findings in a form called Customer Buying Criteria (Table 5-1 shows CBC for Wheel Loaders). However, a more thorough need finding process is usually conducted when each specific projects is started and with a modular development process, the needs and values of a customer has to be documented in a similar form of CBC but on a more regular basis. Changes in products and services that doesn’t synergy with the current business model at Volvo CE of providing fuel efficient and high quality machineries and which aligns with the customer buying criteria’s, are inefficient and doesn’t bring any value to the customers nor the company. In the customer buying criteria, needs are translated to solutions and functionalities in the machine, usually it is several needs that have been satisfied by a common characteristics. The characteristics should influence the design of the modules; hence the modular drivers should derive from the characteristics in the CBCs. Modular drivers thus have to be set to fulfill the CBC of VCE. And if the modular drivers are intended to be used as a design mentality the prominent place of CBC in the development and design process is immensely important.

<table>
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<tr>
<th>Customer Buying Criteria (CBC)</th>
<th>Description of impact on CBC</th>
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| **1. Availability**           | • The machine should be easy to repair and maintain  
                                | • The machine should have excellent reliability, the operator have faith in the machine |
| **2. Performance**            | • The machine must have a good performance, should handle the operators needs when working |
| **3. Productivity**           | • Same or better productivity  
                                | • The production can produce diverse machines; e.g. additional linkage  
                                | • Increase production of machinery |
| **4. Operator Environment**   | • The product should have great quality and be top in the line in the market  
                                | • Easy to operate |
5. **Operating costs**
- Low fuel consumption
- Minimal maintenance costs
- Ease of maintenance and repair

6. **Capital cost**
- Contributes to competitive machine price

7-8. **Safety & Environmental impact**
- Should be sustainable and meet emission legislation and countries national standard
- It should align with Volvo’s Core Values

<table>
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<tr>
<th>Table 5-1 Customer Buying Criteria for Wheel Loaders</th>
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As the customer needs are changing so are the numbers of customized products and services, which ultimately lead to increased number of articles. The requirement of a set of guidelines at Volvo CE which decreases the current accumulation of articles and increase traceability of the support of decisions to change the directions is evident.

Volvo CE are operating their marketing and sales on a global scale and while modular solutions might be a preferable choice of decreasing costs in the business, the aspects of market needs has to reflect the modular designs of the products and services. A module in a product can in one market, e.g. Europe, be a desirable choice while in another market, e.g. China, it can instead be an undesirable solution for the product. There is a need for modular design at Volvo CE but it is a necessity to understand modularity and draw the lines of the modular design at the right places, allowing for future upgrades and varying customer needs behavior on a global scale.

The ability of the modularization to have incentives to drive the development forward is the same aspect which puts stress towards the scenario and process. The specific although generic modular drivers in the MFD process may be too constrained to work with when conducting the analysis and a looser method may be preferred, but which produce the same result. The opinions of the managers at Volvo CE is of great importance on this topic as they have to acknowledge the problem with having strict laws of modularity that may not produce the preferable positive results of modularization on every market when implemented. But if an modularization is to be implemented, all desired markets need to be involved; as the company would otherwise be divided into a modularized and a present structure with no ability to interchange work with each other in that configuration. There would be alienation for the customer in-between the two products being produced between the different company parts/structures. The opinions and decisions of the managers to have the correct incentives and modular drivers of the process hence are of grave importance in order to guide the whole cooperative ship in the right direction for the future.
If Volvo CE can succeed with creating the correct modular drivers for their scenario, new market opportunities are opening which will allow for a more profitable service-related marketing and sales strategy of PSS solutions, see section 5.6.1. There is also room for a more effective developing strategy, since the modularization will allow for a more efficient and responsive structure of development. With a new business network configuration from modularization; Volvo CE can have a rapid responsive network both on an internal as well as on an external scale.

5.3.2 Customer Needs - The Stakeholders and Integration of the Needs into the Product Design and Business Model

When designing for modularity, products and services included, it is essential to include all stakeholders that are somehow affected by the product. It is also important to include the complete life cycle of the products in terms of updated parts or systems, shifting customer behavior and new legislation rules, to structure the product, the services, and the network surrounding the deliverable. As hard as it is to implement modular design in a small organization with only a few stakeholders and products, VCE is facing an immense challenge when trying to apply it to their product range of over 200 products, scattered, on a global market. The need of an easy-to-use and applicable need based modular development method as well as a new business design is evident for a successful modular strategy.

Compared with an integrated design, once the outlines of modular design has been drawn it’s expensive to readapt the products and services from new requirements on the entire modularity. Thus, all stakeholders must be considered before designing the products and services for modularity. The modular development process of implementing the needs in the R&D of the company needs must be based in a language that every involved developer understands and can communicate through. The indication that more and more customized products is evolving on all markets, shows that the development of any company and product benefits from capturing as many customer needs as possible to gain market share. Hence the company must fully understand the customer’s needs on the market, and have employees that understand their part of satisfying the different requirements from the customer.

- Volvo CE must maintain the understanding of the customer's needs for their markets.
- Employees within Volvo CE must have the ability to understand the requirements of internal and external stakeholders.

The consequences of noticing late needs that alters the design of the modules or interfaces can be lost revenue, brand loyalty and market shares. Internally it can result in employees losing their confidence in the organization as a result of not listening to their needs which degrades their ability to perform their work, hence decreasing the productivity in the business. The aspect of understanding each other within the company is not only an aspect of conducting an efficient and good MFD analysis, it’s a necessity of conducting any problem solving. If any pre study is performed with a wrong comprehension of the actual problem, the solution won't bring any value to the actual problem scenario.
Before the modules are designed, all stakeholder needs must be distinct.

The problematic in the current scenario of Volvo CE when introducing a shared architecture in the entire organization is the developing projects that uses a periodic need finding process. In the new environment this can become disastrous since the architecture is most effective when functioning on a global level and thus a need finding process on a global level, including all stakeholders in the development process, would be time consuming and uncertain. Instead VCE should look at the possibility of continuous processes in the business where each stakeholder makes updates on their needs for new generation products and solutions, Figure 5-2. This will ensure that all stakeholders are included in the process and prevent the developers of noticing late needs. It will ease the development of the upcoming interface selection in the architecture and work as an updated source of valuable information for the developers. However since VCE owns a comprehensive amount of products and is operating in many different cultures, they must introduce accountable managers in each region which are integrated in the modular development and has the assignment of collecting needs from respective project groups in each division. Each project group should be responsible of documenting arising needs in a shared network where all needs are easy to trace, see Appendix 3: Regional and Global Need Finding Process. This divides the global need collection process into manageable missions. In a global division, the needs can then be collected in similar document compositions which ease the job of comparing the needs to each other and using them during the developing process of different projects.
When designing the products with new modular solutions and a business network which can handle the new business model, it is important to understand who brings and receives the value. There is always a “why” to how you do certain things and when new solutions are suggested. The question “why should we do like this?” should permeate the solution.

Modular design puts a pressure on the network to handle information flows more efficiently than in an integrated business. Since VCE is operating on a global scale, the needs of every stakeholder in every continent matters if VCE wants their modular solutions to work on a
global scale. Prior to modular design, new solutions on particular markets could make their way into VCEs production line, with the only physical requirement to fit the current solutions. The new business model requires all markets to collaborate into finding similar needs connected to a common architecture with a shared technology.

5.3.2.1 Attitudes in Volvo CE towards Modularity

This section is based on reflections from a limited amount of coworkers at Volvo CE and does not reflect the overall range of employees at Volvo CE. However it is an important aspect to include in the analysis since it reflects some of the actions that Volvo CE should consider.

Through the interviews and workshops at Volvo CE the authors noticed as previously mentioned a negative attitude towards modular design and the modularization project from internal stakeholders. Some believed that it was impossible to perform modular development considering the range of products and the global organizational structure that exists of VCE.

The arguments from engineers also included the lack of knowledge in different equipment areas than their own as well as the degraded ability to change their respective module since it can be shared by additional machines that doesn’t benefit from an alteration. Even though a modular structure is a harsh environment to find and to enable, the end result after the grinding work is an engineering environment where the task of improving the product is simplified to the benefit of the whole cooperation and hence the engineers would benefit in their development work.

Things the engineers seemed to favor with modularization project were the opportunity to change the product and enable new technology within the structure. The initiative of modularization was strongly supported by the managers since there is a great opportunity to change the logistics and production of the company. For instance a modular design to the product and production could enable all the production sites to have the tools to produce all the modules and modular systems i.e. all the machines. This would, despite the high investments in tools, release capital within VCE since the logistics of Volvo CE would be able to be structured in a more efficient way; allowing for regional production and development.

For Volvo CE to work as an organization towards implementing modularity in their products and keeping an effective continuous development of the modular products, there is a need of education in the scenario of modularity in VCE. When the understanding as to why VCE is moving towards a new business strategy and how they are going to transaction while not neglecting their core values is clear, existing negative voices towards modularity in the business of VCE will eventually diminish as the employees sees the benefits of moving towards modularity. It is first when the internal stakeholders understand the clear purpose that they can function as a team and continuously transmitting the needs of their respective field to ensure a "flawless" architecture design of each product.
5.3.3 The Development Process at Volvo CE with a Modular Approach

The process of developing the products and services in a modular environment differs from in an integrated developing process. An integrated process doesn’t emphasize common architecture as a modular process does, since the modular process seek to interchange parts and solutions between the different product types to as great of an extent as possible, while an integrated does not. Hence the informational process regarding internal and external customer needs is different. In an environment where unique product or service specific needs and feedbacks are common, an integrated development process can be more effective than the modular process since it enables ad hoc solutions to be provided. In a modular environment the process of implementing a specific solution is much stricter, if there’s a change needed towards the interface to enable the solution. If the specific solution is enabling to function in the preset interface of the modular design, the modular process is as nimble as the integrated process. If the interfaces function properly in the development process, the implementation of a new function in a product structure is faster, since the solution is deployed to a greater extent and faster due to a shared interface.

Part of VCE’s problem is that the solutions created by numerous development projects have been structured in a way that is iterative and incremental towards improvement, which is great towards the capability of the product. This works great when a company is improving a small flora of products or just separately improving products, since it often generate improved or whole new solutions or new generations of products. But with the current situations at VCE with numerous machineries and parts, the expense of implementing new information is moving towards a peak where the solution and informational inventory of each improvement might cost more than the revenue it might bring towards the company, thus modularity is needed to change the growing informational storage.
The modular development allows for fewer development teams but requires a broader knowledge of multiple machines, ultimately exposing more machines for failures when developing a module. Hence the developing process becomes more critical, i.e. feedback, testing and quality control, in order to minimize the risk of failure in either machine. Because of the current situation Volvo CE is positioned in, where most development is done in an integrated development process, and an approach to modular development requires a rearrangement in the business network design to change the development process.

Businesses that structure their network without the concept of creating value to specific roles are transferring waste in their information flows, leading to an ineffective business, can be disastrous especially when working with modular design in a business. In a modular design, the geometrical and energy specifications in the architecture of the products must be clear for all the stakeholders which receive any form of value from utilizing the information. Irregular information processes in a modular design, with wasteful flows or non-existent valuable connections can result in unwanted decision makings or time consuming processes for the engineers and developers.
Currently VCE is using an ineffective information network where most customer feedbacks or divisional expertise is generally only received by local divisions and specific product ranges. VCE needs to collect the information in a new way and have a centralized organ collecting needs and requirements. To succeed with this the process of the development within modularity needs to support the informational flows with more clear and distinct channels of information back towards the company. Since feedback from a customer who is operating an excavator in one market usually don’t reach the development division of wheel loaders in another market, even though the functional unit of the affected part is very similar or the same of the wheel loader. Finding similar functional units across the product range of VCE will allow for a more effective module development, since the information flows becomes clearer on a global scale, with more valuable informational flows towards the functional unit.

In any business the resources invested by the company must circulate and be re-harvested, recycled and reused for developing new products and services. To make the recycling possible in a long term perspective it is important that the initial product bring value towards the stakeholders, otherwise the iteration of the value will dilute the company. The re-configuration of products will require the engineers to target already existed information about each of the current products to re-create value to the products. The functionality in each machine, part and configuration is currently providing value to each involved stakeholder and engineers must therefore not neglect this in the development process of the new modular products in order to re-create existing value.

With a new business design of modular production, the organization of Volvo CE will look different in a beneficial way; working as a collaborated organization towards a common goal of providing the best set of machines in the market. In recent years Volvo CE has moved away from this when introducing new machineries. The development and research of the new machines have led to the process of solving customer need with the basic requirements of Volvo CE process but VCE haven’t managed to keep up with the problem of having a product flora and organization that grows. This has led to an increasing number of articles being introduced for each new machine developed, and this will change in the future with modularization.

5.4 Business Network Design for a Modular Business Strategy at Volvo

Modularity offers new product designs but puts a lot of demands on the information transactions and organization for future development on the existing modular interfaces and development of new modules. Information on a global scale becomes more vital than before, and intangible value streams from e.g. China has a higher importance for the developers in Europe than before since; architecture interfaces are developed to function on a global scale in the case of VCE and not just on a regional. The architecture of the interfaces, hence need to mirror the stakeholders needs of all markets. If interfaces were developed to fit needs derived from only one region, the company could suffer costly subsequent adjustment from adapting
their architecture to specific markets. Therefore the need of a communicative and serviceable organizational network is of a higher importance than before and requires reconfiguring if modular design were to be a beneficial improvement of the company.

Compared to a commercial e-business, providing end-user equipment or services to the common consumer, VCE instead provides expensive equipment to their customers; requiring more control over the sales to fully satisfy the customer needs. If VCE were to give the same responsibilities as a computer component retailer to their customers, letting them put together their new product without the control of what the customer bought and what he will use it for, it could result in the customer making an order which will not meet the requirements. This could cause expensive consequences in form of remanufacturing and logistics both for the organization and the customer, as well as downgrade the expectations to VCE and undermine their credibility to deliver high qualitative products for and to the customer. However, when configuring the network of the organization it is important to include the characteristics of a successful company in the network configuration; e.g. provide the customer with products and services which meet the needs, responsive support, developed for a successful internal teamwork and reliable deliverance of expected qualitative products.

The modular part industry not only makes the development and manufacturing divisions better and easier, but also improves the sales opportunities and service providing much more efficient. The design of the network should streamline with the modularity of the product-, production- and development-solutions to gain full advantage of the new business plan. Without a well-thought design of the network, the business can never optimize modularity to work on its full capacity.

There is a need for change in the network when developing for modularity; a network with the purpose of increasing the value for the internal and external stakeholders and enabling the development of the modular products and services. It is financially an expensive process and requires a learning process before the stakeholders can effectively start using the network. VCE is today using multiple service systems in the cooperation as a result of takeovers but with the new business design and the financial and experienced assets, VCE can evolve as a company with the new network infrastructure. When implementing the new infrastructure, it is important that a central organ of managers is implemented who control the structure and rules of the modular deployment. These managers needs to be engaged in the ongoing modular improvement in order to fully asset the needs and requirements on the architecture. If the network is to work at its optimum the governance of the interfaces is an important aspect to manage since the value for the stakeholders need to derive from correct interface architecture. Managing the interfaces is a key asset of the modularization, and the only way the long term management is possible if is the network supports the update rate and informational need surrounding the architecture. Thus there is a high value for VCE to connect the interface management with the flow of information in the network and governance within the organization; hence the need of central management of the architecture is evident.
5.4.1 The Importance of a Shared Language in the Organization

Today within Volvo CE all the different departments work simultaneously with diverse issues that are aspects of development, sales or other. Different problems and questions may be issued by different departments to help another department or correct a developing problem. This iterative process of detecting the problem, investigate, pre study, and solving the problem must change in order to enable the best use of a modular approach. The current process of fixing things at Volvo CE is an efficient way of making fixes to problems that are easy to trace. Faulty hoses or broken parts are a relatively simple error to correct. But problems that aren't imminent are harder to correct with this iterative method. As mentioned above, that’s why modularity is sought to be implemented to Volvo CE. Modularity is a way of creating a structure to Volvo CE that prevents problems occurring during development in the future. Operations is sought to be better, easier and more efficient with the modular approach of developing products since everything will be streamlined to satisfy the stakeholders.

Although modularity might be the clear-cut choice of VCE's new development strategy, the Achilles heel of both the iterative process at VCE and the modularization process is the necessity to have a good communication internal and external to the modularization problem. As Volvo CE is working today there are some issues towards communication that is affecting both the future modularization process and the iterative process currently practiced. Even though VCE is having a strong relations on a regional level, the global organization today consists of indicators that reveal the network as inefficient towards a communicative organization; an important aspect in modular development.

• Volvo CE doesn't have a shared documentation structure; making the search for information hard and complex.
• Volvo CE uses differentiated software systems in their global organization; requiring translations when information are transacted between some roles in the network.
• Volvo CE lacks a network design which makes information easier traceable; currently there is a duplication of effort as engineers, developers and designers doesn't necessarily find information which is scattered somewhere in the organization.

The organizational structure and informational processes hence needs a reconfiguration that utilize the fact that a shared language and shared processes is a need of optimal modular development and an effective collaboration within the organization.

• The organizational structure shouldn’t degrade the employee’s ability to understand or communicate.
• Informational unity in the organization to enhance the cooperation in the organization.

If Volvo CE can ensure a shared language and process configuration in the organization it allows them to be a rapid and cooperative organization, which can provide valuable information to all parts in the organization; e.g. understanding the comprehension of a
problem and the need of change. The management of both regional and global processes in the business becomes easier to command and can result in an enhancement of international cooperation through the organization. If modularity should succeed on a global scale, each regional division must have the same understanding of each part of the products which is a step towards informational unity. If each organizational division at VCE operates within the same language, the global development of modules becomes easier; resulting in a less costly, faster, and more secure module development with fewer roadblocks than before.

In the case of VCE, modular development will replace some of the iterative processes earlier used and requires new communicative and coordinated channels. The new design will allow VCE to reduce the number of unique flows going from customer feedback to the development teams since there are less unique parts required than earlier.

• Volvo CE is looking to replace the integral cabins to modular cabins; i.e. Wheel Loader Cabin modular 1 will replace Wheel Loader Cabin Small 1, 2 and 3 and WL Medium 1 and 2

It will also mean that the errors, which are not discovered in the development stage, will sooner be found on the products and parts since a higher number of users are operating with similar designed and configured products and modular functionalities. However, it will be harder and more expensive to perform the test stage of development since it can require the development teams to test it on several product types instead of just one in the integral case.

Also, unique errors and feedbacks might become much harder to solve in the new business model due to the global modular development process and can result in a decrease in brand loyalty; something that needs to be considered when looking at the new informational infrastructure. VCE must be able to catch all the different kinds of problems, both the generic as well as the specific, with regarding both high and low outcome in numbers.

When implementing a modular design the architecture of the interfaces permits the regional organizations to manage the different problems on a regional level, since each module may be attached to each regional customer’s requirements thus enabling easier problem solving when needed just as customization. And the problems solution thus have a faster way of fining the route to the frontline of the product, since each solution is able to be fitted to any concerned interfaced where the error was found. But if the interface structure errors the information of specific errors must be significant enough to reach all the way to the concerned functionality team at the global management, otherwise the interface will not be changed. This puts great stress towards making the correct interface structure of the modularization, since for the customer this error of the interface is a decrease in value since it’s hard to change the modular structure of the product.

For the modular design, communication and coordination are two of the strongest reasons of succeeding with the business model and with a shared language and an effective teamwork this is possible. Coordination is based on the shared understanding of the team’s purpose and
is required to perform complex tasks such as need finding, error analysis or design problems. Coordination can’t however work effectively without organized communication channels and processes. Effective teams require clearly defined responsibilities and delegations and each individual in the teams has to listen frequently and collaborate in order to develop a mutual knowledge around a certain problem. In a team to team or team to organization communicative process, a clear channel ensures the relevance of the teams functioning; meaning that a team needs to have clear directives of where to go in order to find certain information such as modular specifications.

5.4.2 Teamwork towards a Successful Modular Development

In the case of Volvo CE, teamwork is one of the key factors of delivering a prospective effective modular development. The organizational structure must be of a character that doesn’t degrade the teams or individuals ability to develop for the stakeholders needs. The modular design requires a rigid development and design structure to prevent unprofitable changes, but the implementation of modules into the products should likewise not reduce the ability of developing the products or services. To avoid this, VCE should emphasize the characteristics of effective teamwork when re-arranging the network and its processes.

Modular development requires teamwork among all stakeholders to avoid unexpected changes which ultimately affect a stakeholder in a negative way, leading to a decreased value and unprofitable change. Since modular structure is more rigid than integral product structure and parts exist on a wider span of the product flora, changes are more expensive and take more time. As mentioned earlier, modular design also requires all stakeholders’ needs when designing since adjustments are harder in the after-production stage and the teamwork from one team to another therefore becomes more evident. Even though modules sometimes divides and eases the development stage, an effective teamwork process between stakeholder teams must exist to avoid to aggravate other teams ability to improve their module; e.g. module cabin framework must consider interface design for other modules such as the Heating, Ventilation and Air Conditioning (HVAC) unit which eases the service work for the aftermarket team.

For the modular business plan to function on its fullest capacity teamwork among the organization is necessary and with an effective teamwork the organization can become more innovative since stakeholders can find new sources of knowledge and easier understand each other better both internally and externally.

5.4.3 Rapid Network - Information, Logistics and Products

A common expression in industrial economy is known as “time is money” and can describe the rationality of having a fast and responsive network. At VCE the problem when faced to locate information about the business of Volvo CE is prominent, usually the information is found after some time but there are spaces for improvements.
As a global company that is delivering products to other businesses, of which are also operating around the expression “time is money”, both tangible and intangible processes has to be rapid going both through internally and externally channels. Internally information needs to be gathered in a rapid manner and it is usually achieved with a well-thought structure of the informational channels; having clear distinct roles in the network as well as clear locations where specific information can be found. A rapid network is the result of a structured network that is easy to grasp for the stakeholders at VCE and a well-organized network is one of the aims when reconfiguring for the modular business organization.

Modularity is a complement of achieving a quicker responsive network both with tangible and intangible flows, as a result of fewer unique product solutions. A main requirement of the customers of VCE according to the Business Opportunity Description (BOD) is that VCE should contribute with quick maintenance of spare parts and support. The new business strategy of modular products improves the serviceability of spare parts since less unique parts are required by the retailers to provide, which ultimately increases the chance of providers and local producers having the reserve parts in stock. The modular transformation also eases the organization of VCE to supply market segments with products from local production, see section 5.6.2.1. The new business strategy as described however requires a new network infrastructure with a shared language and effective global teamwork for a cooperative, rapid organization. With modularity, a unity of information and language will be a structured and defined setting of handling problems from customers of which seeks support through their retailers or through VCE. As an effect of this, VCE can provide faster maintainability of the customer’s machineries which ultimately would result in an increased value for the customers and an increased brand loyalty.

The rapidness of the network should also reflect some of the processes internally of VCE. Even though some of the processes need accurate measurements which in reality requires both time and money through validity tests, there is a need of processes which in advance tells the company whether it is worth continue to develop. One of the tools in Volvo CE of revealing possible future financial profits in a modular solution is the Global Part Cost Model (GPCM) and calculates the change of future cost or savings in relation to changes in number of parts.

5.4.3.1 GPCM

While there are those in Volvo CE who argues against the GPCM tool of being too general, there are benefits of having a tool of calculating the possible future financial benefits in an early development stage with little effort. The GPCM generalizes the part costs in the entire production of Volvo CE and uses an average cost of the parts included in a module. These costs are divided into three categories: simple, normal and complex parts. With this tool it is then easy for the business to get a quick answer how profitable it can be to replace a number of integral designs with a modular design. It is crucial when deciding upon where to start a modularization project, that the project is based on a beneficial opportunity of profit. Thus even though the GPCM in some cases is to general, it is evident that there is a need for such a tool within a modular deployment.
But just as important it is to have a generic and nimble tool to calculate an average benefit, there is a need for a more specific tool of calculating projects benefits. In the future of VCE’s modular deployment, there should be a more integer calculation model for modular deployment profitability. Then there is an opportunity to both make fast decisions based on generic numbers of profitability and an opportunity to ensure a good business case of a modular project, based on every aspect and the time lapsed for the project.

5.4.4 Traceability of Information

As the iteration of problem solving within the R&D at Volvo CE have preceded the process have grown big due to the vast product flora. The assortment of different parts and services is a derivative from the big iterative development process, and the width of different problems that may occur during usage of the different machinery.

Since each error is sought to be fixed at each machinery type, and the iterative process is just as vast as the iterative process of developing the width of and in the product flora, the teams of engineers that seek to solve a specific problem on a machinery type is in great need of experience of that machine, including the decision support and calculations that gave that machinery its structure. This situation sets a requirement on the organization to enable access to information revolving all the decisions within the iterative processes and the entire product flora's structure. The process of communications and the organizational structure need to support the traceability of the information in order to properly and securely solve the problems occurring. In a modular process, this is just as important as in the present situation of development. Today the traceability of information is not always a clear part of problem solving or development within a product or part. Often the error analysis and pre-study of a mechanical problem is a process that needs dedicated engineers that firmly understand the company and the process structure within Volvo CE in order to successfully retrieve the information needed for each specific problem. The engineers that dedicate their time and work towards solving post production problems often get engaged in a bit of detective work towards the developer’s decision revolving the machines. And these engineers often need knowledge about the people operating in the organization, the organizational structure and the different divisions in order to engage in and retrieve the information.

Through interviews with the engineers that conduct the “detective work” the authors learned that often information is hard to retrieve because not all decision support is documented. It’s evident that this poses a problem towards solving problems within the organization but regretfully since the structure of the iterative process is structured as it is, the allocation of information is just as big of a problem. And the cost and problem of allocation of information is one of the aspects why Volvo CE is looking towards implementing modularization in the first place. This informational paradox appears in the form of a problem of traceability of information and informational waste, or lack of value. In the current iterative development process there is no simple way of resolving this problem, but if the informational processes balance the value in and of information towards as many of the internal stakeholders as possible it is not an impossible situation to evolve the company in. The solution towards
VCE’s scenario is to have a firmer structure towards how to structure and document information, and a clear way of storing it. It is important that the storage is available for the whole company and easy to navigate, since a lot of effort today is put towards retrieving the correct documentation and information. This evidently puts great value towards cutting time and effort within the traceability of the information. It is simple to imagine that the storage should be a common platform for all types of documentation.

The situation of modularity imposes strictly defined architecture and a system controlling how and what information can enter a system or design. The modularization is based around the definition that the architecture and modular interfaces is strictly defined to make the system evolve towards the users and customers, and be nimble enough to change as the market evolves. Hence, the traceability of ownership and documentation of intersection and interfaces between modules is of great importance. And ownership of an interface requires that the interface is only changed or manipulated when the proper information from all involved possible modules towards that interface have been consulted. Changes in the interface has to be strictly monitored by the owner of each interface, so no costly change is made without proper support. Thus a good portal of information which is easy to navigate and understand is of high value to VCE.

As the theoretical part of the modularity states this need of strictly defined information around the internal structure, the conclusion is that the traceability of information has a greater importance when shifting towards a modularized setting. Traceability of the information revolving the modular structure hence may not pose a problem in the company if the system is going to work properly. Managers of the modules, owners of interfaces, developers of the generic internal architecture e.g. hydraulics or electrical systems, and the needs finders towards each function/system cannot be hard to access or their information. The informational process revolving the mechanical development otherwise poses an impossible situation of solving problems and developing the functionality of the modularization since it develops a weakness with a slow information system. Traceability within the informational structure also craves for a structure where the secrecy revolving each of the decision made in these different departments is clear and easy to monitor. Calculations, computer models and decision supports needs to be firmly documented and distributed to the correct channels when needed, so each engineer in need of that support may access the correct information. The common base of a shared language revolving modularity, requirements/needs and informational structure is a necessity for this to work. The opportunity for Volvo CE is to have a vast informational space which is streamlined and don’t puts pressure towards the organization. This structure creates low cost and efficiency. But the informational space must be able to enable all the different disciplines within the modularization work. The platform for the information and the actors within the company need to be able to collaborate with no holdbacks as software problems, problems with finding the information or structure to another or intersecting discipline.
5.4.5 Necessities in a Collaborated Organization - Computing Environment

A necessity within the future of the collaborating modular organization Volvo CE want to be is to have a data environment which supports as many different disciplines as possible to easily be able to access, observe and develop different projects. This environment must be able to support as many as possible of the different software the engineers chose to use during their R&D. It a tall order to support the departments with a platform which enables all the different software, but the reality is that; with a better mentality within the company to use as similar computer software as possible, it will be easier to share information in between the different data actors. It is a necessity for the managers to be able to collect and easy understand the data and computer models that the engineers develop, and it is a necessity for the engineer to understand the manager's incentive and direction for the future of the company and be able to trace that into the computer environment.

To enable this with the strict policy the modularization may need in the future Volvo CE must seek to implement an informational environment where the mechanical and data computer environment may interlink with the software for Enterprise Resource Planning. Enabling the different mechanical engineers and developers who seek to implement modularization to have the same base of computer software with the ability to do all the different kinds of disciplines enables the company to excel in both creating value in the informational space, and in the computer information as well. And for the economic aspect of the platform an ERP system which can interchange information between different departments in a holistic, specific and pedagogic way; set for a situation where the calculation and models for the economic aspects are easy to understand and can diffuse fast over a larger area within the R&D. This may create an opportunity to cross collaborate with and deeper understanding between the economic aspects, mechanical and production in the company.

Evidently this is an opportunity to evolve the engineering space within VCE to a situation where the cross discipline is easier to establish and there is more time and effort left in the employees to deeper understand problems and solutions. In any organization it is preferable to have personnel who have understanding of the correlating or intersecting disciplines as this set to a situation where projects evolve faster and are more clearly defined by the pre study.

5.5 Secrecy and Patent Protection of Modules and Business Strategies

All businesses have confidential papers and information about products, parts or processes that would damage the company financially if it would be released externally. Secrecy agreements and patents protects the company’s innovations, inventions and details about the companies strategies. With the modular design, this becomes more important since each innovation and strategy involves more products, markets and customers.
A modular solution usually replaces several other existing solutions and a change on one module affects a wider span of customers. Therefore, patent protection of modules in the products is evident for the company and can require the company to seek for Patent Cooperation Treaty, PCT, which protects the innovations and inventions in approximately 140 countries, including China which is one of the important future capital asset for VCE. Currently VCE is selling machines in the higher price segment compared with some of their competitors and their brand is instead recognized of selling qualitative machineries in the higher price segment. Since modules in theory decreases production costs, VCE could attract new customers by becoming price competitive to the existing competitors. If VCE would exclude patent protection it allows competitors to use the modular solutions of Volvo CE, with the risk of a reduction in price setting of construction machines over the entire market segment. With patent protection the organization can keep their current pricing while lowering their production costs, leading to an increased ROI and without the risk of other competitors using VCE’s solutions.

Documented information of each modules functionality and specification must be shared among the divisions of VCE for a shared understanding and knowledge of the new architecture around the products, services and processes. The information must be easy accessible for involved stakeholders within VCE to prevent any double development time and to transmit the right information to the right place at the right time. Depending on the stakeholder, the information received can be valuable or invaluable i.e. flow waste. It is therefore important that each respective stakeholder can access and will receive information that is only valuable to him.

Within the organization and the modular design of the products it exist confidential information that is only valuable for certain stakeholders. It is evident that this information shouldn’t be received by other stakeholders than those that it is valuable to. In the term of modular design, there is a new need of confidential agreements since the information about the architecture of the modular design consists of:

- Modules
- Interfaces
- Configurations

The architecture is used to map and document the modularized products and should only be accessible by the stakeholders finding value in using it - e.g. an engineer who’s only looking to optimize the heating unit module of which the function is “to heat”, needs only access to the architecture in the heating unit module and the interface to the HVAC module. Giving that engineer access to the attachment interface doesn’t provide any value to him and is also an unnecessary issue of secrecy.
5.6 New Opportunities with Modularity and the new Business Design

The implementation of modularity introduces new opportunities for the Volvo Construction Equipment when designing the new network design of the organization and product structure. In the future modularity pave the way for new business and product opportunities.

5.6.1 Modularity - PSS and Total Solution

In the future VCE is aiming towards providing their customers with a total solution on site, instead of just producing and selling products, see Figure 5-6. The aim is to be able to provide big and small projects or customers with a solution that fits their need or idea of the project, regardless if there’s a small number of machinery needed or a big number;

**PSS Result Oriented Solution Example:**

- Volvo CE guarantee provision of the service to the customer nonstop with a guaranteed amount of $X$ amount ton material per hour for $Y$ amount USD per month.
- Volvo CE provides maintenance of the machines and requires the use of operators with Volvo CE educational certificate.
- Volvo CE provides education for $X$ amount USD per operator.
- Volvo provides project customers with a total cost offer of operating the project on an estimated time, or by an estimated need of work of the machines.

The essential is to understand what the customer wants to do and be able to fit their need with the cheapest and best solution of machinery configuration to that desire. With a PSS system, known as total solution in the Volvo Group, available from VCE the customers may choose to rent the functionality of a production system or an ensured production rate, or pay for a solution that is guaranteed to solve the project or production in an estimated or predetermined time.

With a modular design Volvo CE enables the service team on site supporting a PSS to be better equipped to maintain and service the products since the modular functionalities cross over many different machinery types and require less parts compared to previous situations. The efficiency of the machinery is also able to be more precisely customized since abilities and functionalities of different product models may be connected and supported in the PSS deal. The different products may have functionalities and options that previously weren’t supported within VCE while VCE still keep the complexity of the part assortment to a minimum. Since the modularity strive to keep the product flora as internally generic as possible, it will be easier to implement different control systems within the products. Future innovations such as augmented reality software and full autonomous production sites are closer implementation and development with modularity and PSS as a base for innovation than in the present structure of the VCE business.
Figure 5-6 Volvo CE is aiming towards providing total solution to their customers (52)

With a PSS structure to the business VCE will have a greater ability to change the customer deal and update the machinery in motion and use. Software may be updated perhaps via interlinks and operations may be monitored and supervised with support of computers. Human error in usage may be reduced by these or different aid and the customer value hence increase due to these aspects.

But even though VCE is moving towards a business model of providing the total solution, with modularity the option to buy the tangible and intangible products is still available, since each customer deal is assembled and customized both with finance and product functionality in mind. Thus a customer’s desire might be ownership of the tangible product, and since the iterative process of improving a modular design combined with returned machinery when a contract has ended in PSS, products will always be available for any cost and revenue efficient ownership.

Volvo’s main part of the organization is currently having a fragile connection to their customers while their dealers have a stronger connection and provides them with products, spare parts while receiving knowledge and other assets from them which are then transferred back to Volvo CE. The customers are therefore relying on the dealers when asking for support. As seen in Figure 5-7, secondary customers receive the products from the first hand customer of which are resold by the dealers.
After the products have been used, there is usually no take-back since there is not enough value in recycling the parts or restoring the products for new customers. With modularity and PSS, new opportunities open for Volvo CE as the restoring of products becomes easier, lower in cost and returns enough value in terms of revenue and intangible assets in order it to be worth doing. As a part of Volvo CE’s business, they already offer their customers a service to renovate their component in the products and it is called Volvo CE Reman. With the new initiative of moving towards a modular total solution business case strategy, it suddenly can be valuable of restoring end-life-products or taking it apart to reuse some of the components or modules for new projects, see Figure 5-8.
In the new business environment, the customer will have a closer relationship to the core part of Volvo CE since the customer is able to connect with Volvo CE to a greater extent. The dealer agencies take a new role in the network of being merely marketers and are acting as receptacles of information. When the customers are considering a new purchase they go through the channels of the dealers which receive information about the needs of the customers which are translated to product specifications. They are also marketers of the various services and product solutions which Volvo CE is providing for their customers; PSS, Volvo CE Reman, Care Track etc. Since the new business model gives the dealers a new role in the network, it possesses a risk that the dealers won’t accept their new role as merely marketers. Their perception of lost revenue due to the new role is a risk towards Volvo CE’s new business plan. However, the new business plan require a continuously service and maintenance of the products which ultimately gives the dealers a shared opportunity of providing the new services and updated products with new parts. This gives a steadier flow of revenue from maintenance of products that is active on a longer basis than before due to a higher degree of service, and total solution and functional agreements. In order to handle possible dissatisfaction from dealers in the new business scenario, Volvo CE should provide them with consultancy in their new roles of solely providing services and information to the customers.

Additional to this, the shared architecture of the products enables Volvo CE to supply the user with direct support channels connected with the new modular information center which provide information about the different modular parts. The idea of having an information center is to give the customers valuable support of the modules and future updates in their products from new generation modules. The center is also responsible of handling the document regarding feedback from the customers. With a shared language implemented in the system and a shared documentation structure Volvo CE can provide the engineers and developers with precise feedback on their respective module and what customer type that used it e.g. problems with hydraulics due to workload, air conditioning, structural damage or desires of more room for storage for the operator. With a shared system of documenting the failures of each module, tractability of information becomes easier. Without module development and a shared processing system, the information which were received by the engineers were slimmed down which made the troubleshooting much harder and inefficient. The new network seeks to provide value for every stakeholder in the system.

In the end-life of the products the reuse of products becomes more valuable due to modularity. When a products life is in the end, it is not necessary the end of all parts in the product. Modularity seeks to ease the decomposition of the products and with Volvo CE's already functioning department service – Reman – the reuse of old functioning modules becomes more evident than reuse of parts in the integral design. This also decreases Volvo CE's industrial footprint since it enables this in local production facilities, see section 5.6.2.1.
5.6.2 Shared Regional Organizations in a Global Business Environment

VCE’s business situation is currently in a global infrastructure with several regional operators processing the businesses in various ways, from production, service, developing, marketing, sales etc. In an efficient organization and team process, it’s impossible to run a business without a consistency in the processes. With modularity there is an opportunity for VCE to rearrange their organizational network infrastructure and keep a consistency in their processes that wasn’t previously fully transparent in the business model of VCE or for the employees.

Modularity seeks to do things in a common procedure by seeking similarities in the tangible and intangible infrastructure and thereby decrease the number of articles, parts and informational waste - hiding the complexity - which will ultimately decrease the amount of the information needed in the business network and create a consistency in the way things are done in the global organization. With more standardized processes and coherent information around the products and services as well as with a common language in the organization in terms of information and procedures, VCE can evolve as a global organization and be more effective on a regional level. Since consistency should reflect the processes in the organization, informational processes in China should reflect the processes in Europe and America. Operating in a consistent way results in an efficient conflict management when faced with unseen obstacles; with the knowledge of where the information can be found to solve the problem. The people faced with a problem usually ask themselves the question of what is needed to solve the problem. With a known informational infrastructure in the organization, the answer can be found faster than with an uncertainty of the infrastructure and the traceability of the information in the solution is improved.

With consistent and well-structured processes through the organization, it is easier for the managers to understand each stakeholder’s roles in the network resulting in more efficient team processes since it allows for easy coordination, clear communication channels, coherent procedures and rapid problem solving. For the individual it becomes easier to understand what is expected from her and who and where he should turn as a result of the clear guidelines the new business model transition towards.

However, the new business model sets high demands on the documentation of information, information unity as well as language unity in the organization since it will become expected in the organization where and what information is found. If information is not equal and the processes aren’t clear, it can create an uncertainty in the organization and result in inefficient team processes. There is also a risk of reconfiguring the processes in each region since it requires a learning process for the stakeholders which are already familiar with the current processes. For the organization it can require educational processes to gain the trust of the stakeholders and explain the new improvements of the network. During the education, valuable feedback from stakeholders can be acquired which can result in new improvements of the network.
In the new business model it will be harder for the individual in VCE to get through with suggestion of improvements since the new business model should strive to emphasize unity in processes, products and services. A risk is that this could eventuate in reduced loyalty internally because of the decreased opportunity to get through with ideas and the engineers could feel that there is no place for creativity in the business. It is therefore important to keep the stakeholders creativity on a high level by including them in the need collecting stage. This should be done on a regional level but included and processed on a global level in the development stage. The need process are periodically repeated to keep the needs updated to minimize the risk of unexpected changes in behavior and technology, and this emphasizes and imposes the opportunity to get the developers and engineers closer to the customers.

5.6.2.1 Local Production and Industrial Footprint

Note; Industrial Footprint is a measurement of stress and demand a company’s operations put on the ecosystems. A Footprint represents the measure of productive land and sea area necessary to supply the resources towards the demand, and to assimilate the waste associated with the actor.

Today the production is set up on the basis that each site is not able to produce all the different machinery, because of the aspects of having specific production tools, storage and the complexity within each product, see Figure 5-9. This has been executed because of the fact that this operational structure has produced the best machines and production sites due to the gradual and iterative growth of the company and products. The negative aspect of this is that not all the requested products of the different customers are available on a shorthand notice. Through different Business Opportunity Description’s (BOD) the authors found that according to the customers, a main aspect of the service of the retailers is to have fast and responsive delivery of tangible products and services in order to deliver a valuable experience to the customer.

In order to succeed with this in the present logistics and production operations, the retailers and service locations need to stock sufficient supplies of service parts and products to be able to meet the demand from customers and prospects. This creates a situation where a lot of capital is bound to be traveling on the logistics channels in form of tangible parts and products, and a lot of capital is bound to be held by the retailers and service workshops. Towards the retailers and workshops this puts stress on them to store supplies sufficient to bring value towards the customer in their service of providing products. It is inevitable for the retailers to hold capital in form of supplies, but in the logistics system there is an alternate way of structuring the operations with modularity.
A valuable aspect of repositioning the manufacturing on a global scale towards a regional production is the opportunity to avoid the problem with exchange rates. With a regional production each site may trade in the local currency and the capital used is bound to be spared from exchange rates with may decrease the revenue of the value created by Volvo CE. An immense opportunity since the capital in the current logistic and production system inevitable is bound to travel due to geographical boundaries between customer and production, and thus will be bound to cost for an expected time. The threat of a constantly changing economy and trade thus will be lowered. And when cost is lowered within the total system of the organization it is possible to lower the price of the product, thus fulfilling the customer expectation with a good quality compared to price. In VCE’s case this will strengthen the core value of quality and secure Volvo CE further as a premium brand within construction equipment.

In line with Volvo’s core value Environmental care, the company have realized and started to analyze the industrial footprint of the organization and operations. In line with sustainability Volvo CE want to lower the industrial footprint and with modularity this is possible. If the whole product range is truly modular any site will with the same production tools be able to produce the entire product flora, see Figure 5-3. Thus all the capital captured in prolonged logistic channels or excessive shipping will be released and the footprint caused by the emissions in the logistics will be lowered. But in the initial implementation of a modular logistics system and production the investment needed is quite big, since the whole structure of production is changed. The initial storage needed at each factory is big, the initial investment in production tools is big and the change in logistics is prone to failure; and the system is dependent on the mentality of just in time to function efficient and at a low cost.
But over a long time span this system is working with a much lower complexity and cost due to the modularization process, hence despite the initial investment it will be more beneficial towards revenue, company structure and efficiency in bringing value towards the end user, customer and sustainability. A sustainable company that is capturing customer value while keeping a low footprint is able to supply their customers while surviving in the future.

5.6.2.2 Regional Idea Generation due to Modularity

A preeminent factor of modularization is to have a firmly defined space of interfaces and modular capabilities as mentioned in previous chapters. But since modularity enables functionalities to evolve via these interfaces and evolving customer requirements, there is an aspect of innovation to be mentioned within these strict rules. As VCE is seeking to adapt the production and logistics operations which enables the industrial footprint to be lowered and sustainability to take a major place in the company, VCE is also seeking to place the production closer to the customer. Since modularization is based on an idea to have strict rules of engagement with the modular system and to collect and use customer requirements within the design, it is evident that placement of the production close to the customer will empower the customer needs finding.

The aspect of innovation is that each regional site may embrace and connect with their customers on a local branch. With this connection the customer requirements might be more evident and the functionality of the product may be improved within the rules of interfaces and architecture. On a cooperative level this behavior of modularization is not to be supported since it means that each location of production may behave differently and it will become impossible to streamline the production and development, and the process of collection of customer needs will not be used as intended. But since all the company’s customer needs are to be retrieved through generic channels towards the development, there may be some evolving requirements or ideas that may be lost. And the ability to tamper with the modularity is not to be regarded as banned, as long as the rules of engagement are followed.

Any modular functionality that evolve from a customer desire might be introduced by the retailers, since the machinery will be customized post production in some cases, anyways and the company then have to acknowledge the opportunity to involve non employed entrepreneurs to introduce their ideas to the benefit of VCE. The new ideas, innovation and functionalities that evolve outside VCE’s corporate structure and rules of engagement can fit the production system since the interfaces of the modular system might not always be changed by non-employees in the development of new functional structures. It then is possible for non-cooperate supported projects to benefit VCE if the projects, concepts and solutions fit within the interfaces and modular structure and is possible to be produced in the production. VCE might have to supervise and control the rules of engagement within the modular system in order to get the process to work properly but also acknowledge the need and opportunities of rogue development both within and outside the company due to the initiative to have local and modular production. VCE may through modularization benefit from their division of special projects.
5.7 Actions towards Implementation – Summarization of Analysis with SWOT

From the results found in the analysis, the different areas were evaluated with a SWOT structure to allow a good overview over the necessities and strengths in each area. The authors found three conceptual solutions which would correlate and solve most of the points in the SWOT analysis in order to enable implementation of modularization within VCE. For the SWOT analysis see Appendix 1: Necessary Actions moving towards a Modularized Design - SWOT Summarisation of Analysis, the following three concepts were found.

5.7.1 Modular Education in Engineering and Technology

To properly implement modularity within VCE and catch all the different customer needs, it is important that the actors within VCE understand modularization and the process the managers choose to implement. A generic and a specific course or education within VCE hence is necessary. To enable the engineers to understand what modularity is and the difference between modules and architecture is the only sustainable way to implement the Core Values into the process, collect and provide for all the customer requirements, impose a shared organizational language, and create a sustaining modular development process. Without an understanding within the organization the development process will not recycle and re-harvest the efforts made within the iteration of the modular development. The comprehension of the subject and process also are the foundation in creating a good mentality and collaboration within the modular teams.

This education should enable the participants to understand the process, subject and the different existing models of calculating and solving problems within VCE which is possible to implement in the modular work. Hence the education should consist of both a generic introduction and a more profound part.

5.7.2 Volvo’s Informational and Computer Environment

Regardless of how good the comprehension is of modularity within the company, the only way to efficiently structure the informational network and enable the engineers to work with modularity is to secure an environment where such process is possible. The shared language of the organization is important to add value with the modularization project, and the language of the different disciplines can only be shared if the different tools of each discipline are familiar to all the different actors. An environment where all software and where decision support is collected and easily understood; enable the company to benefit more from the customer needs since it allows all the different stakeholders to easier trace the functionality and solutions. The computer environment enable a base for the education of modularity to be implemented into solutions and adapting innovations within the company and creates a foundation for an improved organizational network. VCE thus should implement an uncomplicated computer environment to amplify concurrent engineering with modularization.
5.7.3 Improved Organizational Network

With an improved comprehension and ability to work globally with the same process in the same computer environment with different projects, the last aspect of a secure and rapid process to implement modularity is to have an organizational network which supports modularity. It is important that the organizational network return valuable information in a traceable process. The best way to support the customer needs with modularity is to ensure that the customer requirements and needs are a fundamental part of the network infrastructure and modular process. Modularity enables VCE to add value to the customers and products since the organization can improve the network infrastructure and remove wasteful information that aren’t providing any value for specific stakeholders. Instead the infrastructure of the informational flows should base its structure on the idea of creating value to the stakeholders and roles it connects. The effect modularity have on the company is that it will create a renaissance within the company regarding how to collect, document and use information.

The present organizational structure hence needs to change in order to efficiently capture all the customer needs. It will become more essential to enable the developers, managers and engineers to reach the customers and engage with them in customer needs findings.

- The global marketing division
  - Must take a greater position in the need finding process on a global basis. Each region should have an accountable division to collect the respective needs from each department. On a global level the needs are collected and matched against each other to see unexpected changes which could affect the operative regional module or architecture of the products.

- Development
  - Development must now cooperate with divisions outside their current area to find the best possible architecture. This must be done on a more general level since all departments in all markets in all continents can’t cooperate simultaneously. The new need finding process and shared language in the organization is part of the necessities of developing modular products on a global level.

- Aftermarket
  - Takes a bigger role in the architecture since it controls whether a replacement of old modules with new modules should be an easy task or not. The modules should be easily replaceable and the necessity of providing the aftermarket with specific features of each module is essential for this department to work. The need finding of aftermarket divisions becomes more evident than before.

- Soft Products
  - The division of soft products evolves as the development of modules erupts and the transitioning of providing customers with a total solution (PSS) takes a big step. With the new organizational network Volvo CE takes a closer role
towards the customer and provides them with direct channels of providing them with complete service packages.

- Product Testing and Quality Control
  - Because more machines are exposed for failure when designing the products with a modular design, the product testing of modules and complete products as well as quality control becomes more critical. Thus it is important to cross-test the modules with different applications and the testing will be divided into two scenarios. First scenario is concerning modules over a global market and over multiple product floras, and the second scenario is concerning modules that are unique to a specific application and market. The quality in the assembly system of modular manufacturing is improved when separated functional testing is admitted.

The organizational structure thus will pivot around having regional divisions which clearly understand their role in creating beneficial modular designs and value for the global organization and a change is needed to create more clear channels of information and decision support. Innovation within modularity need the process to have opinions and filtering in the right places and an efficient and clear structure to show where sustainability may be improved and the revenue is biggest. Improvements within the organizational network enable the modular education and computer environment to create a modularity with the information collected from the network which pave the way for VCE in Environmental Care, Safety and Quality of the products, services and future PSS.
6 Validity of the Analysis

During the process of analyzing Volvo CE’s current and future situation with an upcoming strategy of providing their customers with modular product and service solutions; workshops, meetings and casual talks with employees at Volvo CE has been conducted. The employees has advanced positions at Volvo CE’s and their objectives have ranged from marketing, finance, strategic team building, development etc., each having extensive experience from being multiple years in the business.

In Eskilstuna the knowledge of the market and customer behaviors in the wheel loader business are broad because it is one of Volvo CE’s main development sites of the wheel loaders. The understanding of the regional business however is more extensive compared to the global business but the general understanding of the business needed in this thesis were well-received from the employees at Eskilstuna. The feedback from the first meetings included possible weaknesses and strengths at Volvo CE which lead to the objectives that resulted to this thesis. To increase the knowledge about a specific objective of the thesis the authors spoke with respective employees at Volvo CE to gain information about a specific question in a specific task. Since the authors had limited knowledge about the present organizational structure both on an internal and external as well as on a regional and global level, several employees who had understanding in the current processes informed the authors about each situation.

As a part of the thesis the authors engaged in a corporate workshop in Braås along with the engineers that are developing the haulers in Volvo CE. The workshop’s purpose was to extend the understanding of the process of developing the products in a modular fashion. The workshop increased the authors’ knowledge about other regional employee’s attitudes towards the new process as well as difficulties and opportunities in the process. It also provided information about organizational weaknesses and future threats of developing and maintaining sustainable modular products.

One of the main stakeholders who provided the authors with information is Tommy Streipel who summarizes:

The job done about the Product Service Systems and Modular Development has been very well performed. The results covered a broad scope as the evaluation was done including multi dimensions (technical, strategy, organization, financial, etc.).

I’m hereby confirming that the assumptions and evaluations in the theses are very well aligned to the real situation in the construction equipment business.

Tommy Streipel
Director, Wheel Loader Product Platform
Volvo Construction Equipment
7 Conclusions

The goal of this thesis has been to study the future business plan at Volvo Construction Equipment of introducing modularity and the modularization project to their future strategic development plan. Two areas have been focused; the modular development process design and the informational infrastructure of Volvo CE's organization in a modular product development context. The research has included literature studies as well as interviews, workshops and meetings with employees at VCE. Studies have found that modularity in the business of Volvo CE is difficult to implement because it requires a lot of knowledge, analyses, and assets. This is true to most modular approaches and in the case of VCE it also concerns a very complex organizational structure and product portfolio.

This paper was set to determine how modularity and the modularization project can help Volvo CE to meet the customer needs and how it adds value to the products and to the customers. It also evaluated the effects of modularity on the service system and information flows within the business and the products. In the study, the implications of the new business plan of Volvo CE and their current situation is also included to determine possible concepts that can help Volvo CE to understand their current situation for an upcoming modular development approach. The paper can work as complementary and tool for the organization of their future development in both processes and products.

The findings of the literature review include the recognized modular development approach, of which Erixon is the author to, and explains the entire process of designing products with a modular structure. The thesis also looked at literatures of designing the network to be as efficient as possible, including the infrastructure of a network which includes both tangible and intangible information flows and the characteristics of efficient teamwork. Lastly the paper studied literature of possibilities with modular design; which were gathered through discussion in between the authors. The literature reviews were then combined with the data collected through Volvo CE to answer the research questions of which this thesis were arranged for.

From the information gathered through VCE, the authors can draw the conclusion that there is a need for change of the current business design, of producing and developing, as the number of parts and products have substantially increased and will continue to do so because of the broadened customer needs and the iterative development process at VCE with integral product solutions. The comparison with case studies and academic research result has shown that this is a strong incentive of moving towards the modular development approach since it in theory and in applied industrial cases, decreases the number of parts while also benefits the business in several other ways; e.g. new opportunities in sales and marketing – such as total solution. Modularity works as a useful motive as to why new configurations in the network are necessary. The new configurations of development, aftermarket and global marketing however require a well-structured organizational framework; shared language and processes, continuous need findings and new channels to the customers and dealers.
Even if changes are needed in the organization before VCE can utilize all the benefits from modular development, they still have a good position of transitioning and configure the processes needed. When transitioning to modular design the organization faces many threats which Volvo CE must be aware of in order to decrease the risk of implementing an unproductive strategy; e.g. low profitability, costly after development, decreased internal loyalty as well as external and lowered quality in products. With the broad knowledge that Volvo CE possess in their organization and with the strong tangible assets, they can avoid the complications if they are aware of the risks and alter their new organizational structure for it. The organization of VCE is shaped to handle changes and can push their new business plan through the organization if they are preparing themselves beforehand.

As a result of this, the analysis suggests the following actions:

(1) *VCE must educate their stakeholders in order to prepare them for the new business model of modular development and the new responsibilities this incorporates.*

The results from the workshops and interviews at VCE indicated a discomfort and uncertainty towards modular development. To properly implement modularity within and outside of VCE and catch all the different customer needs, it is important that all actors understands modularization and the process the managers choose to implement. Without an understanding within the organization the development process will not recycle and re-harvest the efforts made within the iteration of the modular development.

(2) *VCE must reconfigure their informational infrastructure and create a straightforward computer environment.*

The findings at VCE presented dissimilarities in the information infrastructure which is not an option for being successful with modular development since it requires commonality and understanding throughout the organization. It is therefore a need for a change in the network which enables the possibility of configuring the network based on value streams, which ultimately creates a more secure structure of the network. The results suggests that an approach to solve this problem could be to have a shared language, which ultimately means that the organization must change their current computer environment for a more straightforward and shared setting. With a shared computer environment and shared language, the studies suggest the company to oversee their organizational network to function in a modular business setting. The infrastructure of the informational flows should base its structure on the idea of creating value to the stakeholders and roles it connects. The effect modularity have on the company is that it will create a renaissance within the company regarding how to collect, document and use information. Based on that information the conclusions can be drawn that VCE must change their organizational structure and flows to have regional divisions which clearly understand their role in creating beneficial modular designs and value for the global organization and a change is needed to create more clear channels of information and decision support.
7.1 Future Business Opportunities

Volvo CE is today active in all continents and has distribution in 150 countries in total with a total of approximately 80000 machines sold per year for an approximate net value of 6.35 billion USD. This includes products and services e.g. aftermarket, contracts and education.

With the new modular development strategy, they can resell used products with updated modules from new generation with the benefit of using Reman facilities. With the target of implementing modular product sales and development on a global scale, VCE can reduce the costs in the business. This also enables the opportunity of moving towards a PSS – total solution – business strategy of providing the customers with less costly services while providing them the top of the line machineries throughout the complete contract time. As of today VCE has three major customer types in which are purchasing, leasing and updating the machineries. The opportunity in the business case of providing customers with a PSS solution enables the company to create new revenue flows for the company. Instead of providing dealers with tangible products which are sold to customers, VCE provides functional oriented solutions for their customers in terms of agreements that can include tangible products and intangible services. The operational margin received in the new business case exceeds the revenue received from only selling hard products see section 4.4.2.3.

A full implementation of modular development is expected to be used in 2025. The revenue opportunities of moving towards a modular business case is mainly cost savings in production, lead times, development etc. but also includes some new market opportunities and reselling of updated used products. VCE already provides the service of updating used products with new parts with the Reman facilities which will become less costly with the new business case. A decrease in articles is a result of modular development and will result in a reduced range of articles in the aftermarket. This results in an average of 3000 USD/article saving. Because articles are developed and introduced in each new generation of modules, the decrease of cost in development of modular is a fact. Each new part at VCE includes an average cost of 15 000 USD and this means that all unique articles that are removed when develop for modular products saves capital for the company.

The authors estimate that the logistics and regional production will generate an increased performance by 30% based on academic papers and the informational flows will improve by implementing a shared language, clearer informational channels in the organizational network and a shared computer environment. VCE will reach this by implementing a clear process of customer need finding towards the global project of implementing modular interfaces in the architecture, provide the employees with an understanding of modularity and enable them to work with concurrent engineering revolving modularity and different disciplines with a shared computer platform. The authors estimate that the capital which are saved and generated with this implementation surpasses the capital invested in the development process.
When the initial modular development is functioning in each region and VCE has established a common architecture in their business, the following indicators of a successful implementation should have been achieved²:

- The logistics has been reduced by at least 15%
- All products should have some sort of module in their structure
- An initial 30% decrease of parts in the entire inventory
- The assembly time has been reduced with an average of 30% with 50% less errors
- The communication process on a global level has been 50% faster
- Each regional market have an ongoing customer need-finding process
- VCE have increased their operating margin to 18% increased from approx. 10%
- The development time for each product has been reduced by 20%
- VCE have started providing total solution and PSS solutions – selling functional unit
- Higher revenue due to increased margin of providing PSS solutions

²These approximations are based on academic case studies in related industries
References


Appendixes

Appendix 1: Necessary Actions moving towards a Modularized Design - SWOT Summarisation of Analysis

Issues with the MFD process in VCE’s scenario

Strengths

• Within VCE there is a strong and good base of knowledge of the machineries
• Volvo’s products are receptive for efficient modular development using modular drivers, due to the maturity that lies in the products

Weaknesses

• Volvo CE lacks a shared language in the business
• Some negative mentality of the modular approach from the developers and engineers

Opportunities

• An opportunity to share responsibility of R&D over a wider process, but in a controlled and nurturing environment
• The implementation can result in a shared language across the organization
• Modular development increases the shared knowledge base in the business

Threats

• Implications and misunderstandings in the business when changing the development process
• Incomprehension of what modularity is according to the employees will hurt the process
• If the base of knowledge, the process and customer need finding is to lean all the stakeholders will not access the value of modularization
• Volvo CE can fail to get a holistic view of both the future and present situation
• Modular drivers might not be applicable

Modular drivers and Volvo’s current product and service situation

Strengths

• VCE has an established structure and broad understanding for a future modularization

Weaknesses
• Volvo CE lacks the network design to trace some of the information
• Volvo CE lacks a shared global business environment; Volvo’s current environment of regional development, processes and varied language sets is a threat for the continuous development of modules

Opportunities

• Decreases the accumulation of articles and parts due to a common architecture and set of rules which controls the development of new unique solutions
• Modular Drivers may be chosen to clearly direct the company or project at hand
• Modular Drivers enable the company to create a more rapid and responsive network
• Modular Drivers present a clear goal for the company and projects to work towards
• New market and development opportunities due to modularity; PSS, total solution, integrated systems, regional projects

Threats

• If goals are not understood over the complete product range, the company may perform disconnected development on the modular network
• Having strict rules and modular drivers may cause the company to lose the holistic view on R&D (can harm the development)

Customer Needs - The stakeholders and their needs

Strengths

• Modular development is strongly supported by the managers
• Volvo CE already has an understanding of the requirement of including all stakeholder needs in the development process of modularity

Weaknesses

• Complex and vast organization, adaption of a new business model is harder
• Some negative attitude towards modular development at Volvo CE - In the expertise fields of engineering and development, there is a negative attitude towards modularity
  o They see modularity as a way of degrading their ability to be creative since modular development. Their mentality and understanding is opposing modular development.
• Engineers has limited knowledge in other areas than their own
• The current developing projects requires periodic need finding processes
  o In modular development this can require a complex process which is necessary on a global scale and it is time consuming and might result in an inadequate need collection
Opportunities

- The new business model enables for a better collaboration in the organization
- New information channels enables new and increased value for stakeholders
  - More components become the same which enables a sharper knowledge base in the business. Customer to development channels will be clearer and customer needs will be translated into functionalities in the products, which helps the sales and marketing department to tailor-made solutions to fit the customer’s needs.
- Shared technology over the entire organization
- Improving the products is simplified to the benefit of the whole concern

Threats

- Unsustainable need finding if the modular development fails to apply a cross product view of the needs
- The needs and behaviour of stakeholders can shift, they are not fixed requirements
- Late needs in development can result in lost revenue, loyalty, market shares and confidence
- If Volvo CE doesn’t apply periodically updates of needs, the architecture might be insufficient in near future
  - Time consuming need finding process

The development process

Strengths

- A broad understanding of requirements when developing modular products in a Volvo CE premium fashion

Weaknesses

- Volvo CE uses development teams with individuals who has limited knowledge across the product boundaries
- The filtering process of information are currently inefficient for the development process
- The employees filtering the information mentioned above must be fully aware of how the process of modularisation works
  - There is currently no clear documentation structure standards at Volvo

Opportunities

- Knowledge will be shared better within the company
Similar functional units will allow for a more efficient concurrent engineering in modularisation
Clearer informational flows bring more value towards the development teams
  - Defined process designs internally eases the detective work for engineers
The new development process will amplify collaboration within the company
Fewer development teams but require a broader knowledge of the products and processes
There will be less double work made within the organisation since modularity requires defined rules and customer needs in several products can be joined into one solution.
Change the product and enable technology within the structure

Threats

- Modularisation may expose more products for failure when developing a module, due to shared functionality
- It is hard to create a functioning architecture on a global scale which can be sustained in the future
- There will be a waste flow if the information within the development process isn’t valuable for the stakeholder
- Harder to implement specific solutions in a modular environment
- Harder and more expensive to perform the test stage of the development of a modular product
- Expensive to readapt modular products and services
- High requirements on the final decisions
- High investment in modularity

A new business network design towards modularity & Coordination and communication

Strengths

- Strong tangible and intangible assets in Volvo CE;
  - Experienced company with a broad knowledge in the markets
- On a regional level, VCE has strong social relationship channels

Weaknesses

- VCE lacks a common culture in their business
- VCE lacks a shared language in their business;
  - No shared documentation structure
  - Differentiated software systems
  - No coherent understanding about modularity
- VCE has long communication channels on a global level
Opportunities

- Modularity offers new product designs
- Better sales and service providing for customers
- Faster network, tangible and intangible flows are more rapid
- The network will embrace unity and will be easier for the individuals at VCE
- Communication ability on a global scale can be more effective
- Reduce the number of informational flows from customer to development
- Unity in the organization of processes and information results in clearer flows and value streams are easier to manage
- Errors which aren’t detected in the development process will be faster discovered from customers operating the machines
- Effective coordination streamlines complex tasks in the organization

Threats

- The company could suffer costly adjustment if the interfaces are not configured for a global market;
  - Allows for modular development on a regional level with a defined architecture
- Modularity might not work on its fullest capacity if the organizational structure doesn't allow it;
  - Shared language
  - Encouraging mind-set at VCE towards modular design and development
  - Clear processes, how/what/when should processes be performed

The Importance of a Shared Language in the Organization & Necessities in a collaborated organization - Computing environment

Strengths

- VCE already possess all pieces of creating new shared processes and they are willing to listen to each other within the organization

Weaknesses

- VCE has a harder time capturing different cultures in different regions of their development process with the current communication process
- Different computer software within Volvo CE is a problem for a shared language
- The comprehension of the design methodology revolving modularity at VCE is not similar which makes the development and communication process harder;
The employees should have a shared understanding as to why modularity is applied to the business. (The approach of modularity in Scania should not reflect the approach of modularity in VCE)

Opportunities

- With a shared language, cultural and regional needs from stakeholders will be captured
- Shared language will make the operations safer, more certain and easier to run
- Regional and Global issues will be easier to manage with a shared language
- Shared language internationally improves the cooperation within the company
- A common language can help to create an informational unity
- With a shared language modularisation becomes less costly, faster and the process works more secure
- Improved ability to collect needs if everyone is aware of the process
- With a shared language in the organization, communication and coordination becomes easier and results in a rapider network
- Efficiency of the information will be better
- A generic computer environment will enable better cross collaboration
- The computer models created will be easier to share within the company regardless the discipline involved
- Different actors can implement different calculations and information within the data space and thus a synopsis of the projects situation will be easier to monitor and find
- Innovations from other companies will be easier to implement since the computer system might enable more file formats
- A shared computer environment may evolve and turn into something which will fit into the machines and work like an open source environment in the future

Threats

- If the communication fails, the process and project will be damaged and inefficient
- Transition to a shared language might result in translation mistakes
- Expectancy of a specific structure and language which can cause confusion if it is not performed accordingly to defined method
- Results in high informational costs if software and platform don’t work. Employees may turn to old systems
- It is hard to get different software to work with similar file formats
- The functionality of the shared computer space is only working when employees treat it with discipline and don't put informational waste into it
- Cost of implementing new plug-ins or software which previously wasn’t supported
- Access to this environment must be strictly monitored
- Security within the computer system
Teamwork towards a successful modular development

Strengths

- Volvo CE has a good cross functionality between the divisions

Weaknesses

- The current organizational structure, previously mentioned, doesn’t allow for an optimal global teamwork; i.e. non shared language or clear processes and slimmed information etc.

Opportunities

- An effective teamwork helps the organization to evolve, become more innovative and individuals can better understand each other both internally and externally

Threats

- Without a solid teamwork, unexpected changes are more likely to occur which affects a stakeholder in a negative way

Rapid Network - Information, logistics and products

Strengths

- Access to documentation standards to inform employees of VCE’s current and future position (BOD-documents)
  - Rapid way of giving employees who find value in the documents a fast and general view of VCE’s current position and future transitions
- Already developed tools of measuring a synoptic view of the financial opportunity in a quick way of a modular design (GPCM)

Weaknesses

- VCE lacks the organizational structure of an optimal rapid network
  - Stakeholders at VCE sometimes have a hard time discover relevant information

Opportunities

- The modular strategy and the new system can result in a rapider network as a result to a more structured and defined network
• Increased brand value and loyalty - due to improved and faster serviceability and maintainability from the modular design
• Easier to supply markets - retailers and customers - with local production, it is both a faster and more sustainable strategy at Volvo

Threats


Traceability of information

Strengths

• All information is somewhat traceable and exists in the concern

Weaknesses

• It’s hard to implement traceability as to not all stakeholders documenting different work may understand how their operation may bring value towards another stakeholder in the future
• It is hard to trace information in the current network due to;
  o Diverse document handling
  o Reduced information from one role to another in the network, e.g. customer to developer. It is harder to trace the information back to the original source

Opportunities

• Implementing a better informational space will improve the operations, since documentation will be easier to trace and will take less time to collect.
• Traceability of information takes a more central position when the emerging towards modular development
• Good traceability of information makes development easier
• Traceability within information keeps the value of conducted work dormant until the support of that task is needed, and value recycling is hence possible to some extent
• A vast and traceable informational space makes the guidance of the company easier
• Shared computer environment and a shared language makes traceability better

Threats

• An imposed traceability may generate a lot of informational documents, it is important that the information documented actually brings value

Secrecy and Patent protection of modules
Strengths

- VCE has a well-structured patency management

Weaknesses

- 

Opportunities

- Patent protection allows the organization to keep their current pricing, without the risk of other competitors using the same modular solution, while lowering their production costs, leading to an increased ROI and without the risk of other competitors using VCE’s solutions.
- PCT and other patency’s protects the companies ideas on a global span
- Secrecy wise it is important to only permit information for stakeholders in which they can find any value in using the information, therefore secrecy can be a strong incitement of having a well-defined network

Threats

- Without confidential papers and patent protection, the organization could be damaged financially
- Modular solutions are more significant to protect since it affect a larger scale of customers and thus more revenue
- Without confidential papers, VCE could risk documents of the product architectures to be leaked without an insurance of being protected
- Modular design poses a new secrecy risk in the terms of architecture mapping of the products

Modularity - PSS and Total Solution

Strengths

- All tools are accessible within the organization of VCE to establish a complete functional production facility

Weaknesses

- It is hard to attract small- to medium- sized customers to the total solution of Volvo CE

Opportunities
• PSS enable more profitability of the machinery since VCE still have ownership of the machinery
• Innovations may be adapted as they fit into each customer deal
• Total solutions of production systems at customers will slowly ensure that more Volvo CE machinery is working on the market
• PSS enable an opportunity in implementation of the core value of Environmental Care
• PSS will enable a smoother capital flow within VCE
• To supply a customer with a total solution, both VCE and customer may become more sustainable
• PSS and Modularity supply a wide base for innovation
• With PSS and modularity VCE can provide both sales and rental services

Threats

• Errors of the machinery is more fatal to the customer’s business since the total solution PSS rely on keeping the machinery working
• If updates are not made on the PSS machinery the customer’s loyalty might be lost
• The PSS system is not for everybody, normal sales must still be available
• The customer might be too restrictive for a PSS
• PSS needs to work flawlessly to showcase VCE as a premium producer
• The system might need a lot of support in the beginning
• Updates to the PSS might cause problems due to production rates

Regional organizations in a global network

Strengths

• VCE are already established in all continents with their brand and have production sites in most of them

Weaknesses

• There will be a learning curve of the departments in the regions when changing the processes
• Investments on education is needed to get employees to efficiently change the process and way of working

Opportunities

• Efficient conflict management
• A clear consistency and commonality in the tangible and intangible infrastructure
• Efficient problem solving and project dynamics
• Traceability of solutions that rapidly occur
• Managers can easily understand the different stakeholders roles in the network which lead to:
  o More efficient decisions and management
  o Coordination become more easy
  o Coherent procedures regardless geographic opportunities
• Rapid problem solving despite new process
• Decreasing the amount of information needed
• Higher efficiency on a regional level in a global business
• Easier for employees to find the right channels to find help and information

Threats

• If stakeholders don't understand the process changes and the necessities in the process during education, the system will be damaged
• Harder for the individual to run an idea through a project without support by the regional division, which might result in the individual losing confidence in the ability to change and improve the product and service
• Lost loyalty to the company process if the employees don't understand the new necessities within the different process

Local production and Industrial Footprint

Strengths

• VCE already exists in all markets and have established production most continents

Weaknesses

• VCE have separated tools and production structures in their organization
• Regional production facilities might not be willing to share the tools

Opportunities

• Keeps less capital bounded compared to regional transported products
• Ensure a closer connection with the customer; emotional and geographical
• Develop a better service for the customers product and purchase
• VCE could buy supplies and sell their products in the same currency
• VCE would have a broader supply base
• With a local production the industrial footprint will be lowered long term
• Previously travelling capital will be released with a local production
• Customers will have closer connection to the production of the products
• Service and delivery will be faster with local production
Threats

- The initial investment doesn't work and the revenue is lost
- The initial high inventory doesn’t reduce over initial time of implementation
- The Industrial Footprint of VCE won't be affected
- High initial investment
- Hard to keep the quality high in the start-up of the production
- It is inevitably so that some logistics will remain despite a localized production

**Regional idea generation due to modularity**

**Strengths**

- VCE have many production facilities and thousands of employees in fields of development, management and production
  - Broad understanding, local understanding of the market segments

**Weaknesses**

- 

**Opportunities**

- Capture regional solutions and ideas to problems that did not reach the cooperative modularisation process
- Ensure that all customer needs is captured
- Implement knowledge and ideas that normally isn't associated with the product
- A strict modularisation structure enables VCE to integrate future customer solutions
- Innovation has a clear space since each interface enable any new functionality to be assembled to the structure
- Business opportunities may be captured due to that modularisation allow for regional projects to evolve

**Threats**

- Rouge projects within the company may introduce the mentality with the employees that the direction of the supported projects isn't clear
- Rouge Projects might create an idea within employees that the direction of the company is not clear
- The rouge projects may not always produce valuable solutions
- Implementing ideas from outside sources might damage the security of the information revolving the products
Appendix 2: QFD-Deployment for services and the Kano Model

As discussed in section 4.2.2.1, QFD is a quality improvement tool that evolved in Japan to distribute products and services that satisfied the customer needs. The importance of listening to the customer’s voice throughout the entire process of product or service development became evident as it would bring value to the customers and organization, hence increasing the sales of the company.

Since 1983, QFD has emerged outside Japan to North America where leading firms used cross-functional teams and concurrent engineering to improve the products and services of their business. However, these studies were usually applied to pure-manufacturing or pure-service businesses since Product Service System (PSS) businesses were not recognized at that time, even though it existed to some extent. In the 90s, organizations in distribution, healthcare, repair, education, personnel, finance and retail started to use QFD for quality improvement and value creation in the business since QFD works as a suitable tool for structuring customer needs and to assure quality in the otherwise fuzzy and intangible service environment.

According to Mazur, modern businesses differ from traditional. Nothing wrong doesn’t necessary mean that it is the preferable choice of the customer, and improvement of quality doesn’t only mean that the organizations should focus on work standards. In today’s business environment it is important to gain the customers trust and loyalty and this is done by creating value for them, eliminating poor service and maximizing quality.

QFD is developed just for that purpose and helps the businesses find the weak spots of their services by including the customer’s voice into the development and compare the organization with its competitors. It translated the spoken and unspoken needs into actionable functions for service improvements (53). According to the Kano Model there are three different types of customer requirements or needs. There are two types of unspoken needs, the unspoken basic and the unspoken excitement needs.

The unspoken basic needs have no influence on increasing customer value, which mean that the customer expect these needs to be met and are taken for granted. If the organization doesn't fulfill these, there is a big risk that it will cause negative influence on customer value. The unspoken excitement needs can be explained as needs that the customer do not expect. It can be an extra function for a product or simplicity when using it. The last types of needs are the ones that the customer includes in the product specification or can be captured by visiting or interviewing the customer. These are therefore the spoken performance needs. After a period of time, these needs are taken for granted and will be included in the unspoken basic needs. Therefore, the products have to be constantly developing for the products to match the new customer needs. The Kano Model shows what happens if the unspoken and spoken needs are fulfilled and what happens if they unfulfilled, see figure below.
There is little satisfaction when nothing goes wrong and the products or services are meeting the basic needs. Conversely, it is possible to gain great customer satisfaction if needs that are adding something extra to the product or service, ahead of the competitors, are met by the organization.

In a service network the organization are usually part of a chain of flows between different customer roles and it is therefore important to find the keystone customer before applying the QFD. The keystone customer is usually the one who determines the success or failure of the service and if the organization fails to satisfy the key customer the whole chain can collapse (53).

Illustration of the ‘basic’, ‘performance’ and ‘excitement’ needs of the Kano Model
Appendix 3: Regional and Global Need Finding Process
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