BUILDING COMPREHENSIVE MASS CUSTOMIZATION – CASE TRUCK MANUFACTURER

Background material for the animation

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1 BACKGROUND

This training material including the separate animation was developed in the LEKA project’s Mass Customization and Configuration research area. The aim of this project was to study the mass customization at pilot companies and based on survey prepare a training material for the educational and training purposes. The training material illustrates how to build comprehensive mass customization in an industrial company. To be able demonstrate how the projects was carried out, we use “truck manufacturer x” as a fictional case company.

The starting point of the research was to study the current states and the target states of mass-customization at the pilot companies. The study was done with questionnaires and interviews that clarified the state of mass customization in different functions in the pilot companies, following the hills of Mass Customization Mountain -model. As the statuses were studied, development actions were suggested for the companies in order to reach the target state. At this report we discuss through the process and the experiences in the context of the fictional truck manufacturer.

1.1 LEKA project

In order to stay competitive on international markets or in order to access them, a growing pressure has been experienced in companies for the creation of new innovations, development of current products and improving cost efficiency. Especially during an unstable economic situation the objective is to get more added value from existing resources. If these objectives are not met, the effect of the weakening profitability of the companies would be seen throughout the whole of North Savo area as decreasing of employment and transferring of production to lower cost countries. The metal and engineering industries are a major part of the region’s business life. In order to develop the area, businesses and educational organizations have already implemented a number of individual research and development projects. By combining these development measures for the industry of North Savo and new projects, they formed the LEKA project.

The LEKA project was launched in the area, focusing on the machine building and metal and engineering industries. Project is managed by Savonia University of Applied Sciences and it forms a research unit and technology transfer network in North Savo in which the UAS, universities of technology, vocational colleges and development companies work in close
collaboration with industry. The project brings multidisciplinary scientific and applied research as well as the practical implementation effectively together and offers through these connections the possibility to work with international research partners.

With the work of the LEKA project the competitiveness of the North Savo technology businesses on the domestic and international markets is improved. Expertise and cooperation between the different operators are increased as well as the availability of skilled labor is being ensured. From a company’s perspective the results of the project are the project produced research and development support, technology transfer, production of prototypes, piloting of product ideas, improved cost efficiency and manufacturability as well as other matters relating to the development of production. With the help of these concrete and measurable results, the project produces for the companies a clear added value. The companies will receive rapid access to large-scale development resources. The expertise achieved in the LEKA project is transferred to teaching. The companies will benefit by getting a better-qualified workforce.

### 1.2 Mass customization training material

The purpose of the animation and this attached report is to answer a question: *why to mass customize in our company?*. The material is formed in order to teach both personnel and students the answer to this question. It has been developed to be used in personnel training and orientation. Material consists three levels:

Level 1. Introduction to the material & mass customization. (Animation)

Level 2. Benefits of mass customization in different operations. (Animation)

Level 3. Detailed information why to mass customize and background of the material. (This report)

Material is based on the literature study and to the present status and target state analysis in pilot companies in terms of mass customization. Analysis of current statuses and target states of mass customization was made with companies in the following main operations:

- Design and Development
- Production
• Supplier network and logistics collaboration
• Systems, product data & documentation
• Sales & Services.

The analysis was made with selected personnel and from the collected information, results were processed further and actions were written how to get from present state to the target state. After this, the training material (animation + report) was developed.

2 QUICK THEORY AND TERMS

Mass customization is a framework that describes the business operations model of a company that produces customer specific products and services with the efficiency of mass production. Mass customization utilizes modularized and standardized product structures. [Anderson et al. 1997] The benefits of mass customization are:

• Standard structures
• Fewer items
• More items in pull production
• Late variation
• Faster delivery process [Harju 1999].

2.1 Comprehensive mass customization

When developing mass customization, the whole company needs to participate. It needs to be done together and simultaneously. In this project we chose a model developed by Ahoniemi et al [2007]. The model suggests “a mountain of customization” that describes the developing functions as hills and at the top of the mountain you can provide comprehensive mass
customization. The hills are product development, production, supply chain, IT management, customer interface and organization.

![Diagram](image)

*Figure 1: The mountain of mass customization [Modified from Ahoniemi et al. 2007]*
2.2 A Mass customized product

The differences between a mass customized and tailored product are described in table 1:

Table 1: A comparison of tailored product and mass customized product

<table>
<thead>
<tr>
<th>Function/feature</th>
<th>Tailored product</th>
<th>Mass customized product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Structure</strong></td>
<td>Integral</td>
<td>Modular, standard</td>
</tr>
<tr>
<td><strong>Number of items</strong></td>
<td>Large</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Change management</strong></td>
<td>Slow, the change affects the whole product</td>
<td>Fast because of the product structure</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td>Push</td>
<td>Pull</td>
</tr>
<tr>
<td><strong>Sourcing</strong></td>
<td>Order controlled</td>
<td>VMI</td>
</tr>
<tr>
<td><strong>Average throughput time</strong></td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td><strong>Capacity usage in production</strong></td>
<td>Low</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Variation rate</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Change and spare capacity</strong></td>
<td>Weak</td>
<td>Flexible</td>
</tr>
<tr>
<td><strong>WIP rotation</strong></td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td><strong>Value added / costs</strong></td>
<td>Low</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Capacity usage in total</strong></td>
<td>Low</td>
<td>Flexible</td>
</tr>
</tbody>
</table>

2.3 Terms

Module

A module has interchangeable variants that fulfill customer needs. Modules may be different but they have same interfaces. [Soronen 1999, Jahnukainen 1996]

Modular product architecture

Product architecture describes how the functions of the products are implemented by the physical components. Modular product architecture has a “one-to-one” mapping as integral product architecture has complex linkages. Trailers with integral and modular product architecture are presented in the figure 2.
Figure 2: Modular product architecture (left) and integral product architecture [Ulrich 1995]

The lower number of different customer variations is an aim with modular product architecture. When designing a modular product, one aim is to move the order penetration point closer to customer as figure 3 presents.
A/B/C categorization

The products are categorized based on the engineering needed for the customer orders. An A-product order does not need engineering at all. It can be delivered by configuring a product structure on a product platform with standardized modules. The product structure for production is made automatically and production can be started without any engineering. (Assembly-to-order)

A B-product order involves some engineering. This means customizing a single option while the most of the product is based on standardized modules. The load on engineering is very low and only low number of new items, if any is needed. Most of the production can be done with pull production. Only the customized part is order controlled. (Make-to-order)

A C-product is completely designed for a specific customer (engineer-to-order). It has no linkages to other product structures and it is not based on common product platforms or modules. C-products have higher lead times and prices because of the amount of work needed.

Figure 3: Large number of customer needs can be managed with a small number of different modules [Mather 1993]
**Configuration**
Configuration is a method for managing modularized and mass customized products. A variant of each module is chosen for the customer specific product. Besides of choosing a standard variant, configuring can be done by defining parameters in the given limits. [Sarinko 1999]

**Configurable product**
A configurable product provides many variations to be chosen by the customer while minimizing the variation in production. A configurable product is assembled from pre-designed modules and no engineering is needed in the sales process. [Nummela 2006]

**Average throughput time**
The time an item spends in the process. It can be used for describing the speed of work in process (WIP).

**From order to delivery lead time**
The time used form the customer order to customer delivery

**Production lead time**
The time used for production, starting from the assembly start until the finishing of packing.

**Capacity usage**
The used resources compared to the maximum capacity. Besides describing the effectiveness, the number can be used to assess the possible hidden capacity.

**Change and spare capacity**
Describing the flexibility of the capacity. The number can be calculated on different points on the supply chain or on different items.

**Product platform**
Product platforms (see figure 4) represent the components and modules (interfaces) used for several products. The customer products are formed on product platforms.
Figure 4: Product platform consists of more than just technology and components. [Ulrich & Eppinger 2008, MegGrath 2001, Meyer & Lehnerd 1997]

Order Penetration Point (OPP)
OPP (figures 5 and 6) defines the point where the components are “stamped” for a dedicated customer. The customer the time used after the order penetration point as the lead time. Mass customization usually aims at shortening the customer lead time. Hence, the postponing of the OPP becomes important and is enabled by product, process and supply chain design.
Figure 5: Order Penetration Point [Feitzinger & Lee 1997, Ulrich & Eppinger 2008, Olhager 2003, Sako & Murray 1999]

Figure 6: Production assembles the components for the customer after the OPP [Ahoniemi et al. 2007]
LEAN
LEAN is a philosophy aiming at eliminating the waste from the processes. The principle is used to improve customer satisfaction, quality and decreasing the costs and lead times. LEAN aims at having right amount of right components in the right place at the right time with the right quality. Simultaneously, everything that is unnecessary is removed, being flexible and ready for changes. The waste that does not produce any value can be listed:

- Transportation
- Inventories
- Movement
- Wait
- Over-processing
- Over-production
- Defects

Agile production
Agile production aims at flexibility:

- Producing value to the customer
- Being ready for change
- Utilizing human knowledge and skills
- Utilizing virtual partnerships

Leagile
Combined lean and agile methods as figure 7 presents. Leagile is combining the benefits of both philosophies. They don’t exclude each other.
Figure 7: Lean and agile and their means of use. This does not mean that they cannot be used together. [Modified from Mason-Jones et al. 2000]

The benefits provided by agile and lean can be considered as market qualifier criteria and market winner criteria. Market qualifier criteria determine whether the product or its features are applicable to the market and market winner criteria determine whether they are capable of winning the deal. Availability is one driver at the market. Leagile focuses on providing product availability for customers (note figure 8).

Figure 8: The customers get a product right for their needs by combining the lean and agile principles. [Modified from Mason-Jones et al. 2000]
Production control types

Different kind of production control types like Assembly-to-order (ATO) or Make-to-order (MTO) can be used in production and along the supply chain (figure 9). The production control type describes the location of OPP. For example, when an order is received in MTO mode the manufacturing starts. Different components or different modules can have different types of production controls. E.g. cabin can be ATO and the frame can be ETO in the same product.

Figure 9: Different production types.

Work in process, WIP

The value of the work that has not been delivered to the customer.

Modular processes

Similar rules apply for the process architecture as for product architecture in terms of modularity. A process is modular when its components implement one function and when its interfaces are clearly defined. The interfaces should not be integrated to each other but “loosely coupled”. The process in itself can be very complex. A modular process can be customized to customer needs for example in terms of delivery or testing.
Pull and push production
The pull production is a mode where the next phase in production "pulls" components based on the consumption. Components flow through the production process with e.g. kanban method. Pull production usually has lower inventories and WIP than push production. Push production produces products according to the forecast.

Module Identification Matrix (MIM) matrix is meant to define what sub-functions can be integrated and which can form a module by weighting the sub-functions against the module drivers identified. Sub-functions with high weight can be modules and sub-functions with low weight can be integrated with the modules, if there are suitable drivers from both of these to support this. [Erixon 1998]

Design for Variety (DFV) is a “method develops two indices to measure a product’s architecture. The first index is the Generational Variety Index (GVI), a measure for the amount of redesign effort required for future designs of the product. The second index is the Coupling Index (CI), a measure of the coupling among the product components. The design team uses these two indices to develop a decoupled architecture that requires less design effort for follow-on products.” [Martin & Ishii 2000]

Quality function deployment (QFD) is a “method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process.” [Akao 1994]

3 ANALYSIS OF MASS-CUSTOMIZATION – CASE TRUCK MANUFACTURER X
In this section the findings of the analysis are described with the help of mass customization mountain part by part. The mountain consists of five key areas (figure 10) that has to be considered in order to gain full benefits of mass customization. Background information was gathered by interviewing personnel in different operations in order to clarify the current state, vision and actions to be made.
Truck manufacturer x operates globally providing customers both variety of trucks and related lifecycle services. Trucks are designed and manufactured at the factory using parts mainly supplied from subcontractors. The company wants to explore the potential of mass customization in its business. What is the current state, what is the potential, and what needs to be done in order to gain maximum benefits of comprehensive mass customization? Next these aspects are discussed through function by function.

Figure 10: The mountain of mass customization [Adopted from animation]

### 3.1 Design and development

“Case company’s mass customized products are based on common product platforms and modules, which have standardized interfaces. This is done to improve the convertibility of the modules. Product design is measured systematically, supporting clearer dividing of the product groups in the same time. Product updates and customer needs analysis for the product offering is done through a standard process. This way the up-keeping of the old product versions is ensured. Comprehensive product development is organized to support concurrent engineering and the model of stage gate development process model.”
The difference between the mass customized product and the customer specific product is the amount of the new design what is needed to be done for every sold product. When the customer specific product is sold, it increases almost every time the load of the design department, because the product structure might need some changes or the customer wants some feature, which needs modifications in order to fill the needs. This might lead to many problems in product data management if the product development process is not followed, for example the product quality decreases and it makes the order-delivery process slow and increases the product and production costs. When the mass customized product is sold, it is configured from previously designed interchangeable modules, which have standard interfaces and the whole product is based on well-defined product platform. This means that order specific design is not needed at all. [Harju 1999]

In order to be able to sell mass customized products, they need to be designed first. Mass customization is made possible by making the product structures modular. When designing new product features, one feature should fill the needs of many customers or some market area. There is no point in designing one module for the needs of one customer. The market and customer needs need to be analyzed carefully before making the decision of designing a new feature. The aim is to design limited amount of interchangeable modules, which fill large amount of different needs and from which customer specific products can be varied on a basic product platforms. [Soronen 1999]

Well defined modules, standard module interfaces and product platforms are the starting point of mass customization and they form the basis for making different mass customized product variations.

3.1.1 **As-is-state**

In Design and Development, there have been challenges with the current model:

- All product platforms are not designed with the right principles.
- Standardization and use of interchangeable modules is not followed.
- Change management does not take the effects of the change into consideration.
- Manufacturability and production development is not enough taken into consideration.
- Mass customized product strategy needs to be implemented stronger.
• Old structures lifetime is too long.

In the past, when the product platforms have been formed, there might have been made too big compromises. Decomposition of the platforms has not always been done based on the right driver. This has major effects on e.g. purchasing, inventories and production.

The standardization and modularization have already been done but not followed enough. Because of this the future decisions made in design might not have the right information about the effects of the previous changes. Design and production can’t be sure how standardization and modularization have effected on e.g. quality, rotation of inventories, production and sales. For this, one reason can be the deficiencies in the change management, which does not cover the evaluation of the effects made in the engineering of the product structures.

Manufacturability and production development are not enough taken into account in the early phase of new product development, which may lead to bad quality and problems in manufacturability, which increases the costs and the lead time to the customer.

The truck manufacturer x has developed its product strategy towards the mass customization, but it has not yet been implemented as wide as it could be. This, alongside with the long lifetime of old product structures, might lead to large variety in old and new product structures, which needs to be maintained.

3.1.2 To-be

The case company has well clarified common product platforms for different product families, which requires less updating work in design and development and more new features can be developed based on existing platforms. Products and features are decomposed in a clear way to form a module structure.

Type of modularity and drivers for module creation are clear by taking every important stakeholder into consideration and the design needs to be measured in the right way. The design principles for platforms, product decomposition and modularization are based on the right drivers from every key function of order-delivery process, taking the whole life cycle of the product into account. Type of modularity and drivers for module creation are clear by taking every important
Through concurrent engineering, the design and development takes every aspect of the order-delivery process into account, especially manufacturing and production. By looking at the product design from the other functions point of view, the design and development will have the right drivers to guide the design.

To support this and to be able to put more effort on mass customized products in design and development, truck manufacturer implements its mass customized product strategy not only in design and development, but in every function of the company. This means that there is a process also for killing the old products so that they will not load the design and development alongside with the mass customized products.

### 3.1.3 Actions

Recognized key points need to be taken into account during the design and development process in mass customization. In order to succeed in mass customization it is important to put the focus on the identified points, so that the case company is able to design, produce and sell mass customized products. To do this, next actions needs to be done:

- Modularization covers every product
- Modularization is based on standardization
- These actions have named owners.

In order to make modular, mass customized products the truck manufacturer has well clarified common product platforms and there has to be also well defined modules. The module creation has to be based on understanding of the types of the modularity, which are slot, bus and sectional modularity [Ulrich & Eppinger 2008]. After this, the product platforms make it able to use modularity efficiently to match with the large variation of customer needs. Product platforms are formed of common modules, which generate with variable modules a modular system. All product variants can be generated of these platforms and with variety modules they generate a product family. Company’s Design and Development can use product platforms as a base for designing new product families. With these actions, the manufacturer is able to minimize the possible redesign efforts.
In order to take every stakeholder and key function into account during the product development project, case company’s Design and Development uses the Stage-Gate process. This process includes the idea of concurrent engineering and combines all aspects of the functions related to it, so that designing modular products will be successful. Through the use of standard design process, following of the use of standard, interchangeable modules becomes easier and effects of the decisions are reviewed wider.

According to literature, facing these specific challenges can be supported for example by using the Design for Variety (DfV) method for designing product platforms which are based on QFD matrix and approximates of the impacts of variety into the design. The design drivers of robust product platforms in configurable products can be related to improved sales margin and increase in sales. [Nummela 2006]

If the modularization is considered as decomposing the product structure into modules with standard interfaces, the aim is to control their integration in order to achieve customer variety to serve different needs and standardization (components in modules and modules in product families) to get cost efficiency.

To reach these aims and to control the growth of the product structure variants and long product development times in the design and development, one way is to take the next issues into account, which affect modularity and modular product structures.

- Similarity between the production system and the product structure
- After sales and maintenance
- Standardization and late point variation
- Variability
- Strategic properties
- Configurability
- Value chain. [Nummela 2006]
When facing the challenges mentioned in the beginning, in the early phase of the design and development process where the modules are created, design and development can be aided by e.g. the Modular Function Deployment (MFD) method, which aims to develop modular product architecture with good modular structures and known interfaces. The MFD method is divided into the five following steps:

1. Clarify customer requirements (by using Quality Function Deployment (QFD) tool) to define the customer needs.
2. Select technical solutions by using functional decomposition to define functions and sub-functions to form a base on good modular design.
3. Generate concepts by using main module drivers from the whole order-delivery process and Module Identification Matrix (MIM), which identify the modules by examining the relationships between module drivers and technical solutions and can help on integrating sub-functions and modules.
4. Evaluate concepts with focus on analyzing the module interfaces so that interfaces that need better analyzing and improving, can be identified.
5. Improve each module. Point out the main driver behind the module (by using MIM) to be able to design the module according to it. Document all of the modularization data. [Erixon 1998]

In addition to well defined product platforms and modular product architecture, which give cost and time advantage, flexibility and late variation, next key points of the modularization and types of modularity should be taken into account in the product development process:

- Decomposition of the product structure: Functional. After the customer needs are evaluated and product concept is made, the product structure should be decomposed into functions and technical solutions.
- Point of modularization and generation of product structures: Concept level design or latest at system level design.
- Main driver for module creation: Commonality vs. variability, supply chain, configurability, modularity rules, shared modules, platforms, number of drivers, structural vs. functional, company specific, internal and external variability.
• Type of modularity: structural (assembly based), functional (design and development and marketing based) or mix of these two. [Nummela 2006]

During feasibility study phase when the existing options and use of the same platforms and modules are considered, the benefits of the mass customization can be seen in design and development. When products are mass customized and have well defined modular structure, new design is needed only in part of the modules during new product development. This means that the time to market is significantly shorter.

3.2 Production

"The truck manufacturer produces mass customized products with an agile and lean, world-class production system where everyone understands the meaning of providing customer the value by cost effectiveness and flexibility. This is done with modular product platforms and processes that enable their efficient use by pull principles and LEAN / Kanban methods."

The most benefits of mass customization are gained in the production and supply chain. The production is streamlining, the inventory rotation increases, the quality increases and the lead times are remarkably shorter. The mass customization is often thought as a benefit of production. In reality, the mass customization is a strategic choice that needs to be developed in collaboration throughout the whole company. The most benefits are gained by working closely with customers.

3.2.1 As-is state

In the production there have been challenges with the current model:

• The number of pure A-products is low
• OPP is met very early in the production
• A lot of production is push controlled, the stock rotation is low
• Change management is slow
A lot of challenges with the quality

The definition of an A-product is not good since there can be orders with zero hours of engineering and documentation work. Yet, A-products are delivered less than they should and could be. The factory cannot be organized according to A-, B- and C-products.

The order penetration point is usually met very early in the production leading to long delivery times. In addition to not satisfying the customer, the impacts of quality errors can be thus very hazardous. The push controlled production has the same impact as well, but the push control usually increases the inventory levels and slows down the rotation of inventories. There are a lot of quality issues since there are a lot of different components and most of the products are done in the projects as one-off pieces.

3.2.2 To-be

80% of the products are sold and delivered as A-products that include no manual engineering or documentation. This is enabled by, firstly, the clear and understandable definitions of A-, B-, and C-products and secondly, the modular and configurable products.

The A-products’ OPP can be postponed to the later phase in the supply chain as the engineering or purchasing does not have to be done based on the orders. The modular product platforms with proper supply chain and the supplier collaboration enable this.

When the product has enough standardized components the pull type of production can be utilized in A-products. It is necessary to use the pull principle before the OPP where we aim at benefits of mass production. After OPP, when customizing the product, the pull principle is to be used wherever possible. The benefits are seen, besides in shorter lead times, in lower inventory levels.

As a part of efficient supply network, the production works with the Lean principles. By eliminating waste, the production becomes more efficient and faster providing customer more value. And by aligning agile principles as well, the production system can get benefits out of mass customization by being ready for changes and aligning production quickly with volume changes.
Changes are implemented to production according to the change management process. Manual changes without proper documentation are not allowed during the process.

With higher volume of standardized components and working methods the quality of assembly process gets higher. As the volume rises the quality and efficiency will climb as the standardized processes and components are learned.

### 3.2.3 Actions

- A product development project
  - New products where the modular product platforms are designed throughout the whole product portfolio aiming at postponement of OPP and lower number of different items
  - Defining the A/B/C products
- Implementing Lean and agile production systems
  - Kanban, pull controlled production and inventories
- Implementing a change management process
  - Developing and training a well defined change management process that is properly used and enabling quick changes

### 3.3 Supplier network and logistics collaboration

“The truck company x manages a global mass customizing supply network that drives for full chain benefits by transparent partnerships and collaborative improvements in order to provide high quality and cost effective products for customers that get products right for their needs.”

The most benefits of mass customization are gained in production and supply chain. The numerous benefits of the supply are mostly driven by a modular and standardized product platform design. Biggest benefits are speed, quality and low cost. The product that is sold is a result of the whole end-to-end supply network. All the value that is created along the supply chain needs to be valued by the customer. As in production, it is necessary to utilize the benefits of mass production before the OPP.
3.3.1 As-is state

In supply network and logistics we found the following challenges:

- There are more than 300 suppliers of which most are local
- Pricing is related to order size
- There are quality issues
- Suppliers are not involved in product development
- Forecasting is done manually and it is not reliable
- Contracts are made only with the first tier suppliers
- Some suppliers cannot evaluate their capacity and are unable to communicate challenges with the factory
- There is visibility only until the 1st tier suppliers
- Most of the suppliers deliver with push principle
- Vendor managed inventories are used only for small fasteners
- Auditing and evaluating of suppliers are not done regularly
- Contracts do not support deliveries based on forecasts
- Inventories are mostly at the company x and the updating of inventory management parameters is manual. There are buffer stocks collected 2 weeks before the production start.
- The purchasing takes care of sourcing and operative purchasing

The more there are suppliers the more there are contracts, orders, deliveries, quality issues, item numbers, collaboration methods, and people needed to take care of them. As the most suppliers are local the benefits of global or LCC sourcing are probably not utilized.

The order batch size related pricing makes it expensive and unattractive to order small batches.

Six sigma or lean capabilities are not implemented throughout the supply chain leading to quality or delivery reliability issues either at the factory or at the customer.
Suppliers and there capabilities are not utilized in the product development projects as much as possible. Suppliers have low or no visibility to the upcoming products and have low possibilities to affect them.

Forecasting is not done properly with automated and integrated collections of sales forecasts. The updating is not done regularly which may lead to bullwhip effect at the supply chain. Bullwhip effect means the accumulated inventory growth or material unavailability at the upstream or downstream supply chain. The company cannot help or control the 2nd tier suppliers if the contracts are only made with the 1st tier. Also, the visibility is limited only to the 1st tier leading to difficulties of seeing the challenges at the 2nd tier. 1st tier challenges can be seen if they are communicated frequently and well enough with the end manufacturer. Long term forecasts are not updated regularly and the forecast structures are incorrect.

### 3.3.2 To-be

The supply chain will be driven into more open and transparent collaboration network. The aim of the supply chain is to provide customers the most value. The efficiency in costs, lead times and quality are done with mass production principles like pull principle.

Truck manufacturer will drive at having fewer 1st tier suppliers. However, all the outsourced components need to have a second source. Having fewer 1st tier suppliers leads into simplification and thus better control and management over contracts, deliveries, items, quality, inventories, product development and the whole supply chain. Flexibility for changes and volume fluctuation are easier with fewer suppliers.

Suppliers are involved in product development projects. This way the manufacturability, quality and reliability are high already at product launch.

The outsourcing of logical non-variable entities is enabled by a modular and standardized product platform design. The value for the customer is significantly increased with customization. In order to maximize the benefits of that value creation, the customization is to be kept within the company. This is enabled by collaboration with suppliers and purchasing of only fixed materials. As an example the figure 11 illustrates a cabin purchased with 10 items of which one is a standard frame and the other 9 are option items. All the material is delivered to
the factory according to forecasts and inventories. These components can be combined into 64 different end variations.

![Diagram of cabin modules]

**Figure 11: Example of cabin modules**

This kind of standardization improves the forecasting and planning as well as there are not so many different items and suppliers to be managed.

The aim is to apply pull principle wherever possible and minimize inventories through the whole supply chain. Purchasing of some components is automatized controlled by Kanban inventories. Components are delivered and produced just in time.

### 3.3.3 Actions

Some recognized actions to enable the comprehensive mass customization and improved sourcing and supply network functions

- Implementing a global sourcing strategy
o Forming partnerships with suppliers locally and abroad in order to make the customer the most value
  o Open and transparent network

• Implementing Lean & six sigma principles throughout the supply network
  o Kanban inventories operating with pull principle
  o Quality improvements and audits

• Information systems development
  o Transparency and automation to purchasing

3.4 Systems, product data and documentation

“Truck manufacturer x has world class information systems driving for flexible but accurate configurations aiming for more BOM A-products. This is done by state-of-art tools that have clear interfaces and are integrated with suppliers up to necessary level. Improvements are done collaboratively with supply chain and product development organizations.”

The comprehensive mass customization model is enabled and highly dependent on the modern information systems. Systems provide the transparency, flexibility, speed and reliability.

3.4.1 As-is state

There are challenges in the current operating model and systems. The challenges can be defined as:

• BOMs are configured manually by “minus-principle”
• Only 60-70% of sold products are with BOM
• It is difficult to implement the changes of products to production
• Components are purchased with old drawing revisions
• Not enough visibility to suppliers
The configuration of sold products is done manually with deleting the options that are not sold to the customer. The sales need to know which configurations are available. There is a lot of tacit knowledge used when selling and configuring a product.

Only 60-70% of products are sold with a BOM structure. In mass customization system at least 80% of the products should be A-products that have a BOM structure.

Changes made to products are not done properly to production. There is no clear defined process for changes or it is not used. The timing for changes is not done properly causing challenges in production. The systems aren’t flexible enough for changes throughout the network.

Suppliers have the latest revisions of the drawings but sometimes the products are ordered with old revisions. This causes challenges when the components do not fit. The supplier does not know which revision is the ordered one and which is the newest revision.

The capacity and order book of suppliers is not seen. It is difficult to estimate the supplier’s capability to deliver.

3.4.2 To-Be

The configuration is integrated to the CRM system. The configurator has an interface to the PDM system where it gets the latest product data, configuration rules etc. The sales select the options that are formed into a BOM.

All the products in the manual are structured according to BOM. This improves significantly the management by reducing the number of managed structures.

A process is created for product change management. Once a product change is made it gets a date when it is implemented to the production. The changes are visible and understood along the supply network. Old revisions are ramped down as the new is ramped up under control.

The systems increase the visibility along the supply network. For example, forecasts, plans, sales data, product data, schedules and order book are shared up to necessary level with suppliers. This increases the transparency and guides the operations of each player along the
network. The primary drawing format is 3D models in order to avoid confusions with supplier and its quality.

The master data management is doing collaboration with all the functions in order to improve production, suppliers, product development, sales, life cycle service unit and of course the customer satisfaction.

### 3.4.3 Actions

- Implementing a new configurator
  - Tacit knowledge is "in the configurator"
  - Implementation project is done with Master data, production, supplier network, sales, life cycle service business, and design & development

- Products are moved into BOM structure
  - All A-products in the catalogue are BOM`s
  - A-products represent at least 80% of the sold and delivered products

- Developing and implementing a process for component/product sunsets and sunrises

- Suppliers are integrated to the systems. Suppliers get the relevant data.

### 3.5 Sales and services

“Company’s products are developed to be modular and same time based on customer needs, which is done together with the customer by approved process. Short delivery times are ensured by selling mainly BOM A-products. Customer will get products which combine long life cycle, quality and maintenance. Through the mass customization and the modular product structures modernization and life cycle services can grow to cover the whole product range. By including the item management to this, customer will always get the right spare parts. The sales process itself is improved by using a sales configurator.”

The difference between selling a mass customized product and a customer specific product is the time that the customer has to wait to get the ordered product and the cost of the product in the whole life cycle. Other aspects are the quality and the level of after sales services and also the larger variety of different standard features, which are better in mass customized product.
3.5.1 As-is-state

In Sales and Services there have been challenges with the current model:

- Too many product platforms.
- All products are not based on modular structures.
- Global needs of new product features differ in the design process for long time.
- The process for gathering customer needs is slow and it is not continuous.
- Sales manual has old structures, which are not up to date.
- Sales do not use a sales configurator.
- The whole life cycle of the product has not been taken into account in every function.
- How customer and sales are committed to mass customization.

Too many product platforms make the up-keeping of them in the design difficult. This leads to lower quality, which makes the products harder to sell. All products that can be sold to the customer are not based on the modular structures, because until now modularization has been based on a few product lines at a time.

The decision making process is challenging between different regions because of their different needs, based on the different customer expectations. Also the process for gathering customer information and needs is not defined well enough. This might lead to wrong drivers when new products or features are designed.

Sales department is able to sell products, which are based on the old structure. This makes the after sales business more difficult when they cannot know for sure what kind of product has been sold for the customer. One reason for this is that the sales department does not have a sales configurator, which prevents them from selling products, which are based on the old structure.

The life cycle of the product has not been taken into account fully in every level. For example, if it is not taken into consideration when choosing a single component for the product, it might
have bad affection on the spare part sales. In the end, the most difficult thing in implementing mass customization may be to make customers buy the mass customized products.

### 3.5.2 To-be

Manufacturer sells trucks, which are based on a few, well clarified and flexible common product platforms and standard modules for different product families. They are well tested, have better quality, shorter lead time, have good spare part availability and make modernization of the machines easy.

As modules, interfaces and platforms are standardized and the processes are also standard, they can be measured so that it supports mass customization. The process for gathering customer need data is continuous and it takes different market segments into account and makes the decision making faster. Customer interface generates the right drivers for the Design and Development process.

Company’s sales use the sales configurator, which makes the order clarification process faster and easier to manage. The sales configurator handles all the relations automatically when customer specific products are sold. It also makes sure that the product data is up to date and saves the structure also for the use of Life cycle service unit and generates all the needed documents and the structures automatically.

Through ownerships, items, modules, platforms and whole products are designed so that the whole life cycle is taken into account. When new product is designed or old product is updated, it must be done so that decisions benefit also the business in the end of the life cycle.

The sales will get proven results of the benefits of the mass customization through the well implemented company’s mass customization product strategy. With these benefits the Sales and the whole customer interface is able to get the customer by mass customized products.

### 3.5.3 Actions

Recognized key points need to be taken into account during the design and development process in mass customization. In order to succeed in mass customization it is important to put the focus on the identified points, so that the truck manufacturer is able to design, produce and sell mass customized products. To do this, the next actions need to be done:
• Modularization covers every product
• Modularization is based on standardization
• Continuous customer data gathering process
• These actions have named owners
• Clear responsibilities for the item, module, platform and product owners who also manage the life cycles
• There is a “sunset” process for killing old products
• Sales configurator is put into operation
• Convince the customers.

Growing modularization to cover every product is handled by product development projects. Beside this there should be also a process to decide when a customer specific need would form a standard module. This is supported by the continuous customer data gathering process. In updating and developing products, there are item, module, platform and product owners who take care that during the modularization and standardization, as well as in updates, also the life cycle is noticed in the decisions. This means close work with between the Life Time Care and the Design and Development. Besides this work, there has also been developed a “sunset” process for the killing old structures, which are not wanted to take into modularization or which are not selling anymore.

The mass customized products are managed in the sales by the sales configurator software, which handles the configuration knowledge. The customers are convinced of mass customized products by making them more desirable by emphasizing the benefits.
4 REFERENCES


