



EXPLORING DESIGN FOR SUPPLY CHAIN METHODS IN NEW PRODUCT DEVELOPMENT PROCESS

Case: Large lawn and Extra-large leaf rakes

Lappeenranta–Lahti University of Technology LUT

Master's thesis in Mechanical Engineering

2022

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ABSTRACT

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Mechanical Engineering

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Exploring design for supply chain methods in new product development process

Master's thesis

2022

59 pages, 17 figures, 5 tables and 2 appendices

Examiners: Juha Varis D.Sc. (Tech.) and Amir Toghyani D.Sc. (Tech.)

Keywords: Design for supply chain, design for logistics, DFSC, DFL, new product development

In product development projects it is crucial that the internal stakeholders have a mutual and clear view on the goals and targets of the project. With the current disturbances concerning supply chains and logistics performance it has become increasingly important to take into account also the needs of supply chains. With the methods of design for supply chain (DFSC) and design for logistics (DFL) it is possible to achieve benefits for both product design teams and supply chain teams.

This research is going to map the current state of the case company's situation concerning DFSC and what kind of improvement potential there is. The key tools used are a literature review a semi-structured interviews and concept designing based on both of these.

The results indicate that many benefits could be achieved by implementing DFSC to current company processes. The method could be also used in other applications inside the company to break the silos between departments.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

LUT Energiajärjestelmät

Konetekniikka

Eero Takala

Design for supply chain metodin käyttö uusien tuotteiden suunnittelussa

Koulutusohjelmasi ja tutkielmasi: Konetekniikan diplomityö

2022

59 sivua, 17 kuvaa, 5 taulukkoa ja 2 liitettä

Tarkastajat: Juha Varis D.Sc. (Tech.) and Amir Toghyani D.Sc. (Tech.)

Avainsanat: Design for supply chain, design for logistics, DFSC, DFL

Tuotekehitysprojekteissa yhtiön sisäisille sidosryhmille on tärkeää olla selkeä kuva ja projektin mittareista sekä tavoitteista. Nykyisten toimitusketjun haasteiden vuoksi myös toimitusketjun tarpeiden huomioon ottamisesta on tullut tärkeämpää, sillä niillä voi olla merkittävä vaikutus tuotteen kokonaiskustannuksiin. Design for supply chain (DFSC) tai design for logistics (DFL) metodia käyttämällä on mahdollista saavuttaa sekä toimitusketjun, että tuotekehityksen tavoitteita palvelevia parannuksia.

Tässä tutkimuksessa paneudumme toimeksiantoyrityksen tuotekehitys prosessin nykytilaan ja mahdollisiin kehityskohteisiin DFSC:n näkökulmasta. Tutkimustyökaluina käytetään kirjallisuuskatsausta, puoli-strukturoituja haastatteluita sekä konsepti suunnitelmaa edellä mainittujen pohjalta.

Tulosten perusteella olisi mahdollista saavuttaa monia hyötyjä ottamalla käyttöön DFSC metodeja. Näitä voisi käyttää myös laajemmin muissakin yhtiön prosesseissa.

ACKNOWLEDGEMENTS

What a ride it has been. As a true optimist it surprised me how pessimistic and right can people be concerning my planned timetable of this thesis. Nevertheless here we are on the brink of graduation.

Big thanks to the fellows at the commissioning company for providing me with this opportunity and fuelling it with genuine interest towards DFSC and sparring me along the way. Also big thanks for the continuous support from professor Juha Varis and professor Amir Toghiani, with the clear guidelines for the thesis, it was like a light in the end of the tunnel for me to follow.

Sincerest regards,

Eero Takala

ABBREVIATIONS

Abbreviations

BOM	Bill Of Material
CDC	Central Distribution Center
DFL	Design for logistics
DFMA	Design for manufacturing and assembly
DFSC	Design for supply chain
DFX	Design for Excellence
EPAL	European Pallet Association
ERP	Enterprise Resource Planning
F2F	Face to face
FTL	Full truckload
GMA	Grocery Manufacturers Association
ICT	Information and Communications technology
ITO	Inventory turnover
JIT	Just-In-Time
KPI	Key Performance Indicator
LTL	Less than truckload
MBX	Master box
MOQ	Minimum order quantity
NPD	New Product Development
PAL	Pallet
PC	Pieces (individual products)

PO	Purchase Order
RBX	Retail box
RDC	Regional Distribution Center
SC	Supply chain
SCM	Supply chain management
TMS	Transport management system
UX	User experience
VAS	Value Added Services
VUCA	Volatility, Uncertainly, Complexity and Ambiguity

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1 Introduction

In this thesis the processes related to a product development improvement process called Design for supply chain (DFSC) and design for logistics (DFL) are going to be covered. They have similar nuances as more prominent methods like Design for manufacturing and assembly (DFMA) and Design for excellence (DFX). DFSC and DFL combine product development with logistical and in wider scope supply chain improvements. These are increasingly more important to combine due to current disruptors for global supply chains like diseases, conflicts, energy market fluctuation and inflation. These can have severe consequences to overall costs and profitability of businesses.

1.1 Supply chain management

According to Goldratt (2014) goal of supply chain management is to increase throughput while simultaneously reducing both inventory and operating expense. In this context throughput refers to the frequency of product sales happening to customers. For different markets the throughput happens for different reasons. In some markets the customers value and are willing to pay for good service and on other markets the customers are just seeking for the lowest cost.

Definition of supply chain is a network between an organization and its suppliers to make and distribute goods to a final buyer or customer. Supply chains represent the track of getting a product or a service from its original state to the end-user and thus transferring value to the customer. (Sharifi, Ismail and Reid, 2006.)

According to Hugos (2018) the difference between supply chain (SC) and logistics is that logistics is considering only the movement and storing of goods while SC has more comprehensive approach where also the coordination between different parties is considered. For example sourcing, transportation, manufacturing and sales. In short supply chain

includes all the steps that are impacting the end customer in the end and logistics is just a part of this chain. There are conflicting needs between the various stakeholders inside the supply chain. For example sales and customer service might require a high inventory level to be able to maintain high service level and to satisfy any sudden demand increases but then supply planning and warehousing might need to reduce inventory to lower the capital stored in finished goods inventory and warehousing costs and to decrease the risk for obsolete inventory. (Hugos, 2018.)

The global supply chains have been affected by the rapid changes in the international competition environment (Gereffi and Lee, 2012). For supply chains to run smoothly they require precisely timed movement of goods, services and information (Mentzer, 2001). These global SC's move finished goods but also raw materials and semi-finished goods so that the businesses could gain better competitive performance. (Gereffi and Lee, 2012). For example sourcing goods overseas can benefit from lower production costs, tariffs, trade concessions, capital subsidies, better access to markets and close proximity to customers or markets. (MacCormack et al. 1994; Ferdows, 1997). Sourcing refers to activity in which the aim is to achieve lowest total costs for acquiring goods or services. The difference between purchasing and sourcing is that sourcing includes all the steps before the operational buying activity like contracting, finding suitable supplier and negotiating trade routes (Kerruish, 2016). This is not the complete truth as in the long run businesses should not align their decisions purely on cost reduction and short term incentives in mind but more based on their mission, values and long-term strategy (Meixell and Gargeya, 2005). A Company can also choose to outsource productions. This means moving the factory operations overseas. The benefit with this is usually significantly lower costs but the flipside is much longer supply chains and longer lead times. (Harland et al. 2005.)

There are also other risks involved in outsourcing production. For example the desired cost impact can be lower than anticipated and thus the magnitude of savings will not be achieved. Also more complex supply network of outsourcing can cause unpredicted issues as has happened during the Covid pandemic for example the complete halt of port operations in Chinese cities. The risen transportation costs have eaten away much of the previous cost

savings. Also the public opinion can turn against the previously domestic company which decides to outsource. (Harland et al. 2005.)

There are also other risks related to global supply chains. For instance due to more complex supply chains, management problems are more prominent as there are multiple stakeholders involved in different countries and cultures. Also material and information risks increased with complexity (Meixell and Gargeya, 2005).

With the more complex supply chains of outsourced operations, agility could be the key to be able to maneuver more quickly in sudden shocks inside the supply chain. Also having factories in multiple locations would increase flexibility as in, if the shock hits one part of the global supply chain other operations could take part of their tasks and thus continue to supply the demand. (Sharifi, Ismail and Reid, 2006, 3-4.)

According to Hugos (2018) each SC has their own characteristics but the main legalities remain the same. All companies need to make decisions and actions in at least the following five areas. Production, inventory, location, transportation and information.

Production – What does the customer want? How much, what products and when should be produced? Production also includes physical production scheduling by taking into account plant and workload capacity, quality control and equipment maintenance.

Inventory – How much inventory and in what stages of SC should be stored? What amount should be kept as raw materials, semi-finished goods or complete products? Primary goal of inventory is to act as a safety mechanism against uncertainty in the SC. Keeping inventory is expensive as the money used to produce the goods in the warehouse are not generating any profit and maintaining warehouse drains money. Thus it's crucial to optimize inventory levels and know when to order more.

Location – Where to establish production and inventory locations? What are the most cost-effective locations? Should you rely on existing facilities or build new ones? When these decisions are set they determine the possible routes from production to customers and also the risks related to these routes.

Transportation – How to move the inventory through your supply chain? Air-freight or trucks are fast but expensive and sea-freight or trains are slow and contain more uncertainty. This uncertainty can be cushioned by stocking more inventory. When should you choose what mode of transport?

Information – How much and what data should be collected and what should be shared between different stakeholders? Correctly timed and accurate sharing of information is key to better coordination and decision making. With solid information it is easier to decide what to produce and where and how to transport it. (Hugos, 2018).

1.2 Logistics

According to Cagliyan et al. (2018, 133) logistics is a framework which consists of processes of planning, executing and monitoring the physical flow of products, services and information from the creation point to the consumption point to meet customer demand and assumptions.

In this system, logistics is made of the activities which allow the correct product for the correct customer at the correct time and place. This is called Just-In-Time (JIT) method. The goal of JIT is to minimize waste in the overall flow of goods and services (Kotler & Armstrong, 2004, 419).

With this method businesses can gain advantage over their competitors by providing the desired product in the desired quality and quantity when and where the customer needs it in

a reasonable price. Simultaneously businesses can acquire competitive advantage as the result of carrying out an effective logistics chain, by providing superior customer service or by providing products at a lower price point. (Pienaar, 2004, 9.)

Logistics has a large contribution in customer satisfaction, improvement and maintenance of cost structure of businesses. It is noteworthy that the rapidly growing markets and the gross national products of countries have also large share of logistics in them. With these in mind logistics can be considered a performance dimension for the businesses which directly affects the profitability and viability of them. (Bilginer et al. 2008, 1-2.)

1.3 Current business environment

Fast advancements of technology and shifting market dynamics have been altering the business landscape for current business models. The rapid development of information and communications technology applications has enabled the possibility for any enterprise to compete in any marketplace. This change is affecting everyone disregarding geography, whether the business is in manufacturing or services, non-profit or profit everyone is now competing in a bigger pool with pricing pressure of a global marketplace. (Gautam and Singh 2022, 98.) These settings are called VUCA which translates to volatility, uncertainty, complexity and ambiguity and these can create unforeseen obstacles for unprepared companies (Bennett & Lemoine, 2014).

From the September 2022 issue of McKinsey's economic conditions report the most prominent risk for business growth is inflation. Also geopolitical instability and current conflicts are still seen as big risks to global growth for the next year. Supply chain disruption is not seen any more as such big affecter although the situation is still not normalized to the levels before the pandemic. In Europe, especially fluctuating energy prices and grim outlook on domestic economies casts a dark shadow to the business environment. Also 9 out of ten responders to the survey cited to be seen price increases during the past six months and most of those have pushed at least some of this increased costs to their prices. Most also see that the operating expenses will be increasing for the businesses during upcoming months.

There is a wide discrepancy between responders from different regions. In Europe both the current and upcoming global market situation are seen as bad. But in China the views are mostly positive. This could indicate that China has started to recover quicker than Europe.

1.4 Current global supply chain situation

In the midst of Covid-pandemic according to Gartner (2022) companies are not heading towards “new normal” but more towards “no normal” an environment which has constant uncertainty which will require innovations, flexibility and money on data and analytics strategy. With these the businesses can have a better chance of maneuvering through future crises.

In figure 1 it can be seen a snapshot of the global supply chain pressure index from beginning of 2018 to end of September 2022. Goal of the index is to show how much disruption there is in the global supply chain by using range of indicators. The GSCPI uses transportation cost data from Baltic Dry Index (BDI), Harpex-index and U.S Bureau of Labour statistics. It also uses data from different regions considering manufacturing. The areas are China, Euro-area, Japan, Korea, Taiwan, United Kingdom and United States. (Benigno et al. 2022.) We can see from the index that there has been significant disruption beginning just after mid-2019 and although it has come down from the highest peak it is still significantly higher than before the pandemic.

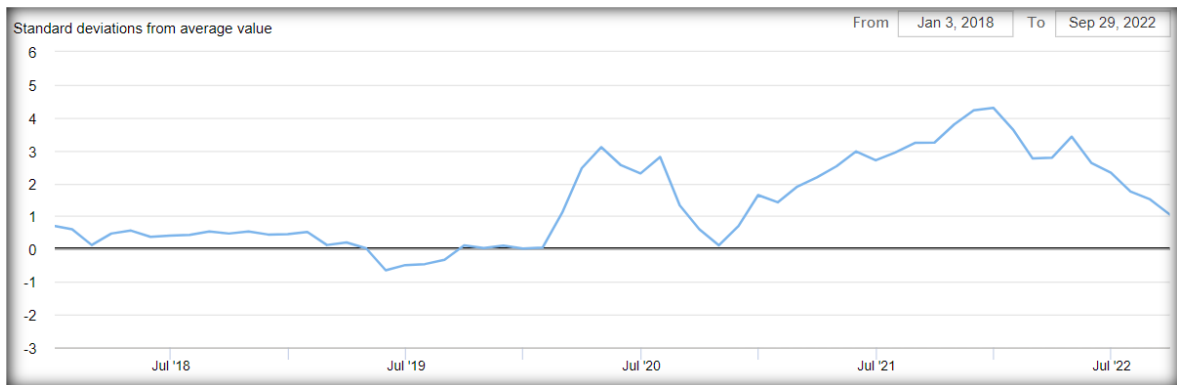


Figure 1. Global Supply Chain Pressure Index (GSCPI) portrays standard deviation from average value (Benigno et al. 2022)

From Figure 2 we can see the price evolution of Forty-foot-equivalent-unit container (containers will be discussed more thoroughly in chapter 1.13.1) prices from China to US West coast and from China to Europe. The data set shows data from beginning of 2019 to beginning of July 2022. We can see here that in beginning of July 2022 the costs for the containers at US market was 7 400 USD and for European market 10 500 USD so both are roughly at the same level as year prior but still significantly higher than before the pandemic.

According to Murray (2022) big part of the supply chains recovery ability rests on China and their ability to keep production and port operations running. One major improvement was Shanghai's lift of Covid restrictions and thus their large port could begin recovering. Although China is slowly recovering there are signs of new wave of Covid rising (Reuters, 2022) Issues still persist also in Europe due to the close proximity of the Russia's war against Ukraine and the sanctions on the Russian trade are complicating trade routes particularly from Asia.

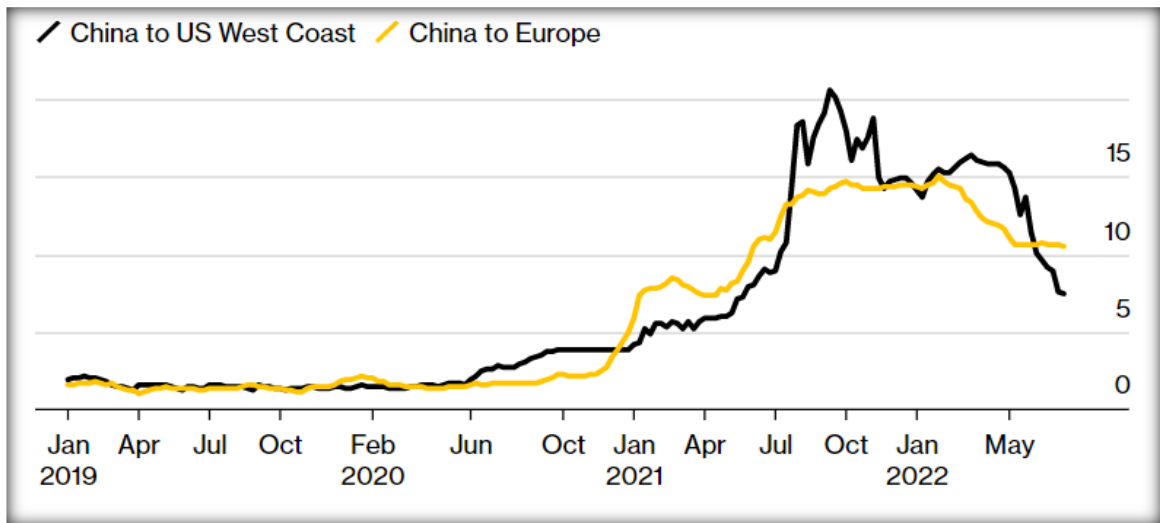


Figure 2. Forty-foot shipping container (FEU) rates in 1000 USD's (freightos.com)

Logistics has become more complex because of the disruption caused by latest world events. Transportation costs have increased globally on all modes of transport and according to Gartner's Risk management survey (2022) logistics and shipping were the most important disruptors for supply chain for the past two years. Globalization and ease of access to alternative goods has put more significant weight to product design. And product design affects for example the quality, materials, manufacturing methods, regulations, laws and what kind of supply chain will be used. In general sense the success of SC depends on the product design and vice versa. (Velling, 2021.)

In the McKinsey's Global Survey of September 2022 the responders were asked how their SC's are expected to change in the next three to five years. 44 % of the responders estimated that the SC's will become more regional or more local, focusing in the close proximity of the countries or municipalities in which they are doing business. And only 24 % of the responders said that their SC's would become more global.

1.5 Scope and justification

In the research there will be taken into consideration design for supply chain and design for logistics activities and making a literature review on what can be found from existing papers.

What kind of existing research has been made. With this information a guide will be created to be used in the case company's new product development process (NPD). With this tool both product developers and supply chain personnel can gain insight what kind of improvement potential the project at hand has concerning each other's areas of responsibility.

This subject is critical due to risen supply chain related costs across businesses and thus there is significant pressure to find solutions to tackle higher costs. Cost of containers was on its peak in the summer of 2021 when a used FEU container costed 351 % more than before the pandemic. Plus there was a significant container disparity between the parties sourcing the products / services and those receiving them. This means that the sender has shortage and the receiver has abundance of containers. (Leman.com). Also by implementing DFSC/DFL method it is possible to lower the overall carbon footprint of the shipped products as by optimizing container fill. With this it is possibility to fit more products in the same container and thus spread the transports carbon emissions across more products.

1.6 Research problem

Due to increased logistics costs there is a pressure to apply the higher costs directly to product prices instead of decreasing profit margins or by trying to find solutions to decrease the logistical costs per product. Currently the case company is providing customers with ready-to-use products with no need for assembly before using (The case rakes). This has been the desire for long from sales teams and business area's perspective. The case rakes are also positioned differently in the portfolio than for example rakes with quick-detachable rake heads. There is also increased pressure to find more sustainable solutions in the overall product design and logistics process as customers are increasingly aware of these aspects. (Haleem et al. 2022).

1.7 Research questions

How large sustainability/cost reduction impact is it possible to achieve by applying DFSC method in NPD process? Focus on product design alteration and container and pallet fill-rate.

1.8 Research goals

The goal of the research is to find tools and ideas to tackle supply chain and product design related issues in the new product development process (NPD). The end-product of the thesis could be an addition to current NPD-process at the case company and also a concept design of the case product with DFSC aspect in the spot light.

1.9 Research methods

By conducting literature review on the subject of design for supply chain and design for logistics the plan is to gain wide perspective on how these methods have been used in companies before and how they could be implemented in the current processes at the case company.

For gaining deep knowledge about the ways of working in different function and processes inside the case company an empiric research is conducted with semi structured interviews for different stakeholders concerning the new product development (NPD) process and supply chain at the case company. These stakeholders are supply planning, product design, packaging design, logistics, sourcing, warehousing and product management.

With the literature review and the empiric research the goal is to create a conclusion and based on that a concept design for possible solution for the research problem in the form of new product design and a part of a toolbox in the current NPD process.

1.10 Design for supply chain

DFSC is a framework which aims to optimize product's design with supply chain. It is quite clear that the moment the product design is completed and approved the following supply chain related decisions are difficult to change thus limiting the flexibility and evaluating more efficient alternatives for supply chain, or it might require significant design alterations after that. (Gokhan et al. 2010). For many companies the design of the supply chain comes many steps after designing the products, this is due to the fact that the role of supply chain is failed to see as part of product design process (Velling, 2021).

According to Cargille & Fry (2006) problem with DFSC is the diffusion of responsibility due to the fact that supply chain cost savings are rarely reflected in the performance score cards of the designers or marketeers and thus the incentive to invest in taking supply chain into consideration in the design process is non existing.

At Hewlett & Packard (2006) practical steps concerning DFSC of printers were to keep the devices cube shaped and robust to make it simpler to pack them and to cut extra padding out of the packaging. Also cables and other accessories were stored inside the printer to further reduce packaging size and thus fit more devices per pallet. They also used barcodes instead of user manuals, this allowed the user to scan the bar code and receive instructions in their preferred language instead of having tens of instructions in multiple languages separately in every package. At HP different functions worked together using different techniques instead of an across-the-board push for improvement. With this method they could achieve aggressive cost savings and deadlines with less bureaucratic approach. This method is a four-step process to develop and spread DFSC practices. The steps are:

1. Prove the concept with early wins.
2. Formalize the concept.
3. Formalize the program.
4. Accelerate adaptation.

The goal of the first step “Proving the concept with early wins” is to show for the internal stakeholders the viability of the concept by showing success stories from the early processes. By awarding these early wins a positive and exciting environment can be build which will generate further opportunities and more responsibility for those creators of the winning factors.

In the second step “Formalizing the concept” it is all about making it simple to understand for everyone what the concept is about. At HP they developed a DFSC “Six-pack” which includes variety management, logistics enhancement, commonality and reuse, postponement, tax and duty reductions and environment & take back. In figure 3 these are explained more thoroughly.



Figure 3. DFSC Six pack at HP (Cargille & Fry, 2006)

Third step is to “Formalize the program” in this step a team is formed which will be responsible for carrying out the DFSC best practises for the organization. In this stage it is beneficial to assign specific project management and support resources and also place incentives and clear goals for the measured metrics. These factors will increase the engagement of the project team.

The fourth and the last step is “Accelerate adoption”. This means that for the organization to adopt DFSC there needs to be enough focus given for implementing these DFSC techniques across multiple products. In this stage it is crucial for the management to direct resources so that value can be generated and thus discovering applications for DFSC. This is a difficult task as many companies tend to be fast moving and the company structure is multinational. Thus these value-opportunities may not be in one location, they might be spread across many product lines and countries. This makes DFSC difficult to implement.

For the sake of identifying these opportunities at HP they are using DFSC opportunity assessment framework. With this the limited time of managers can be used most effectively and the benefits of DFSC can be explored and the teams guided to focus attention to relevant product lines. The idea of the assessment is to evaluate each of the six pack techniques to find opportunities and to assess if they have potential. The whole assessment takes six weeks for data collection and analysis plus a week-long face to face workshop. The stages of the assessment are presented in figure 4.

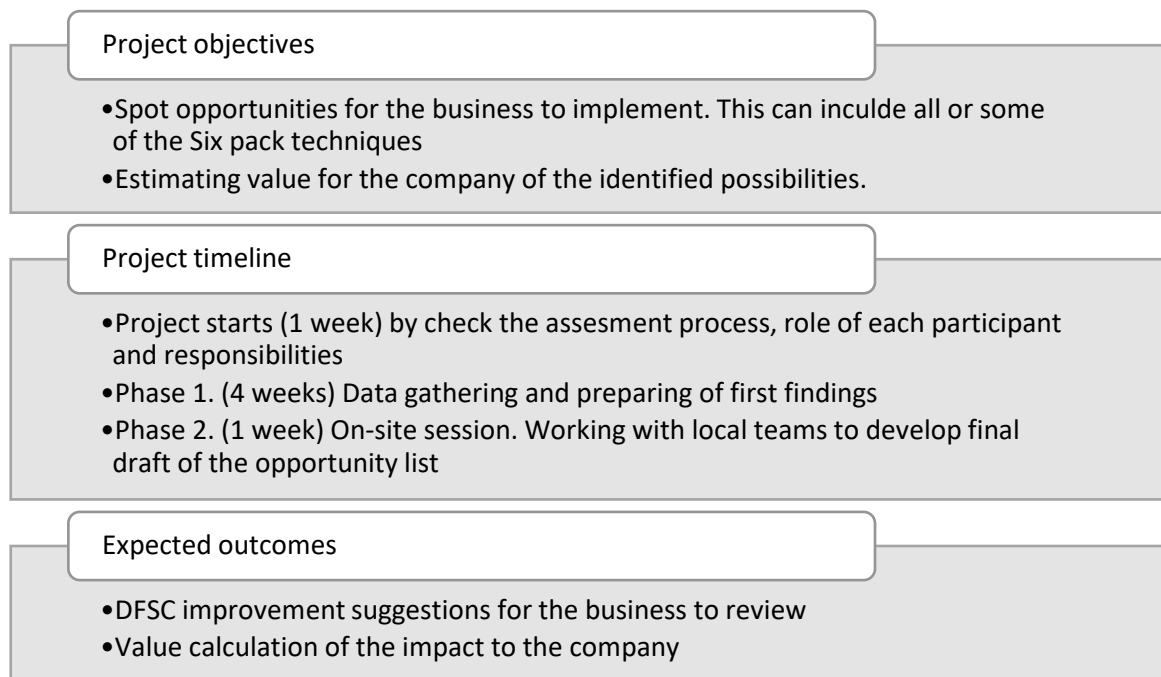


Figure 4. The opportunity assessment stages (Cargille & Fry, 2006)

DFSC has been studied in other researches also, like one by Aldanondo et al. (2005) which focused how to integrate product family design and supply chains. In this study a diverse set of customer's functional requirements were mapped. These requirements are focusing on different products in a product family and they have specific service levels to satisfy the needs of the customers. With this mindset the product family can be divided into sub-assemblies of which each is responsible to satisfy a specific portion of customer needs. The goal is to define this product family, so that it can match any demand and simultaneously controlling the supply chain performance. This process has two steps:

1. The bills of material (BOM) provides process, easily define errorless BOM:s for the predefined requirements of the customers. This is a pure product design step.
2. Optimizing the compromise, in which the supply chain is selected and the composition of the product family is selected.

This method is based on iterative design in which the cycling happens between these two processes as seen in figure 5. As an output from this process will be the detailed product family design and detailed supply chain design.

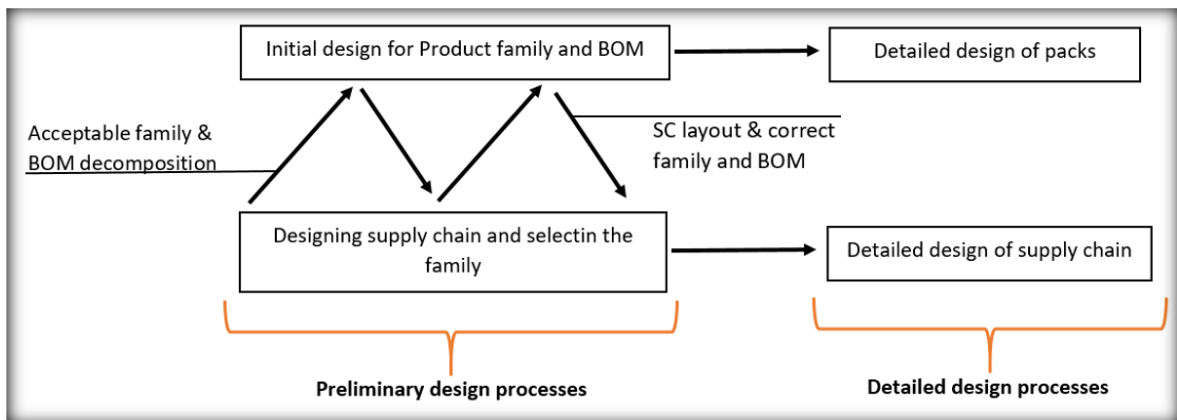


Figure 5. Iterative process of proposed DFSC approach by Aldanondo et al. 2005

Another study from Wang et al. (2004) investigated supply chain and product combinations and their interactions. They proposed three variations of supply chain and three different product types. The suggested SC's were lean, that specializes in lean manufacturing and cutting costs, agile, which focuses on shortening the lead time by making manufacturing faster and more flexible and lastly a hybrid supply chain which combines abilities from both lean and agile. The product types are functional, innovative and a hybrid product. This study, even though had a product-driven approach, was focusing more in helping to make the decisions for appropriate vendor selection rather than purely combining logistics and product development.

The key findings from this research is that to be able to combine product design and supply chain it is key to find a model which shows demand generation and satisfaction aspects. But the researches from previous decade were more focused on finding an optimal solution to supply chain optimization. So DFSC model which would target both SC and product design optimization was not extensively tackled. (Gokhan et al. 2010.)

1.11 Design for logistics

Design for logistics (DFL) is a design method in which the logistical processes are taken into consideration during the initial product design phase. It has slightly narrower scope than DFSC as it focuses more on the physical flow of goods. DFL also includes logistical characters such as usability, cost, quality, supportability, on-time-delivery and the functional requirements of a designer. (Dowlatshahi, 1999, 62.) The successfulness of logistics relies on the businesses ability to use the technology that can contribute to business performance and solutions providing customer satisfaction (Bilginer et al. 2008, 1-2).

According to Dowlatshahi (1999, 62) DFL can be divided in four subsections. Manufacturing logistics, Logistics engineering, Design for transportation and design for packaging. These sections should be simultaneously analysed and executed during the design phase (Chiu & Okudan, 2011, 146; Dowlatshahi, 1999, 59).

In figure 6 are described the elements of each subsection of DFL. **Logistics engineering** is involved in the supportability of products and systems throughout their whole lifecycle. Logistics engineering is also involved in subjects like safety, measurements, manufacturability, logistical costs of the product and reliability. (Gnanasekaran et al. 2003, 2.) Also the environmental aspects should be considered by a logistics engineer. These include life cycle analysis, solid waste management and energy savings.

Manufacturing logistics is concentrating in the productivity of the manufacturing operations as it is one of the key contributors in DFL.

Design for packaging is enhancing the appearance of the product and thus helping with the marketing of the product. It is desired also to increase protection from the elements to safeguard the products path in the logistics chain.

Design for transportability is a crucial section in DFL as transportation costs directly affect the profitability of many businesses. With an effective transportability design a business can achieve competitive advantage, reduced prices of goods and serviced by using reduced scale economics.

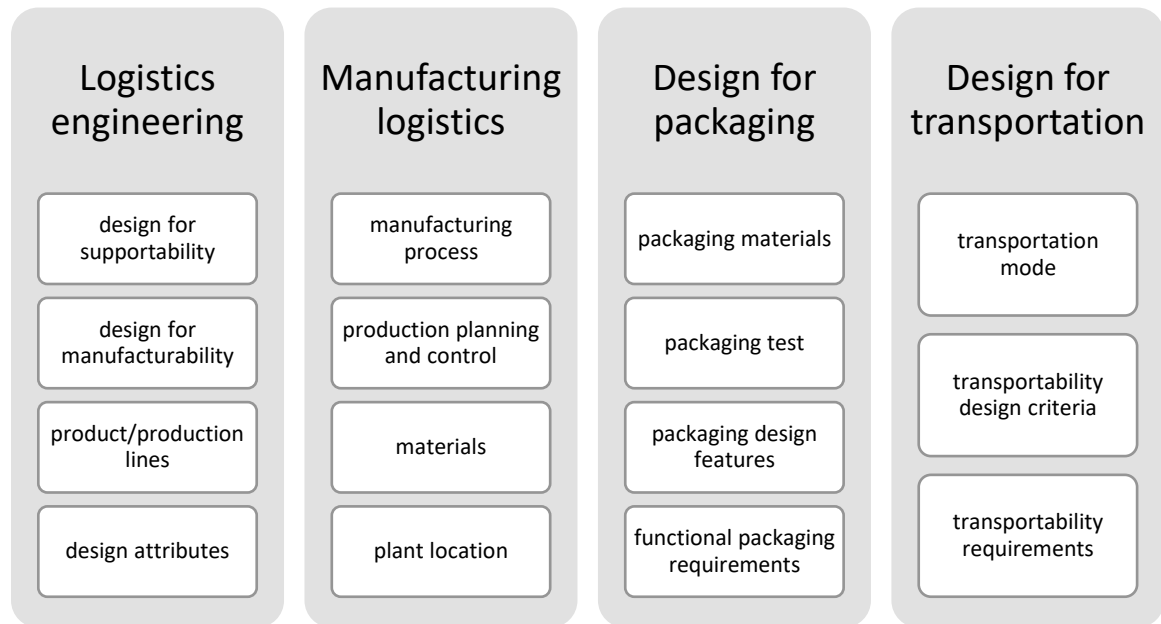


Figure 6. Hierarchy of Design for Logistics structure (Dowlatshahi, 1999, 64.)

1.12 Benefits of Design for supply chain & logistics

The decisions made in the product design phase cement the next development steps and thus affects agility, product customization, supply chain and product life cycle costs. With a good cooperation among product development, marketing, manufacturing, finance, procurement and supply chain teams, can increase the value of the product and simultaneously reducing the overall costs.

With a honed DFSC strategy the business can increase supply chain visibility, responsiveness, communication, lowering product costs, time-to-market and risks related to

supply chain. With these perks the company can achieve competitive advantage over its rivals in the global market. (Velling, 2021).

Logistical efficiency is an important competitive tool for businesses. It not only adds value to the business, but also increases value provided to the customers and overall success of the business. Today's rapidly changing business environment is pressuring companies to be more dynamic. Competition between companies is more and more turning into competition on logistical excellence (Kotler and Armstrong, 2004, 419). In DFL product design phase also the capabilities of the partners in the logistical chain are considered. And this is why it is decisive to explore the full scope and capacity of the logistics process during the design process. (Kao, 2006, 34.)

According to Kao (2006, 34-36) DFL can be used as a system approach to establish the functional requirements of a designer and to determine also for example logistical requirements, cost, volume changes, supportability and ordering intervals. Further a business can use postponement and flexibility by implementing delayed product differentiation, partnerships, localization, simultaneous processing of different products and taking apart old ways of working. For these reasons DFL can be seen as an important design strategy supporting and strengthening the development of logistics.

1.13 The standards of transporting goods

The focus concerning transportation routes is from China to Central Europe as that's the route the case company gets the case items (The case rakes) in this thesis. Also keeping in mind the routes from Central distribution center (CDC) to Regional distribution center (RDC) and from RDC to customers. As the packing and palletization of the products differs on how they are transported from the factory versus from the DC to DC or to customers.

At the case company products are transported in containers and the containers are filled with pallets (PAL) which contain master boxes (MBX) which contain multiple retail boxes (RBX)

and the retail boxes contain multiple products (PC). Next we will go through the characteristics of each of these transporting “vessels”.

On purely cost reduction mindset it is important to implement correct package size with correct minimum order quantity (MOQ) size to enable full containers with each purchase orders (PO) placed at the supplier. With this it is possible to maximize container fill and minimize waiting time at the factory for completed products. Because if the PO includes less products than full truck load the supplier might wait for production of other products to finish to get a full container. Or they can send a partially filled container which means the logistical costs for the container are distributed among fewer products which means higher logistical cost per product. There is also option for Less-than-containerload (LCL) shipment which means combining the products with other products of other parties. This means that you are paying only a portion of the container space. This can mean longer lead time for the container to reach the destination as it needs to go through whose ever products it contains.

1.13.1 Containers

To transport goods safely but efficiently across long distances nowadays is a standard to use an intermodal container or as more commonly called a shipping container. The benefits of a container are that it can be loaded on different kinds of transport vehicles such as trains, trucks and ships without the need to tamper with the goods inside. Also around 95 % or all containers fit the measurements of ISO standards so most freight transport systems have the hardware to pass these containers through without a hassle. (Lewis, 2017.)

Table 1. Container measurements (Finncontainers. 2022)

Container type	20' DC	40' DC	40' HC	40' HCPW
Lenght	6050 mm	12200 mm	12200 mm	12200 mm
Width	2440 mm	2440 mm	2440 mm	2500 mm
Height	2590 mm	2590 mm	2896 mm	2896 mm
Inside lenght	5890 mm	12010 mm	12010 mm	12010 mm
Inside width	2330 mm	2330 mm	2330 mm	2440 mm
Inside height	2370 mm	2370 mm	2680 mm	2680 mm
Carrying capacity	28000 kg	26000 kg	26000 kg	25110 kg
Floor-space	13.7 m ²	28.1 m ²	28.1 m ²	29.3 m ²
Volume	31.8 m ³	66.4 m ³	76.0 m ³	79.0 m ³
EUR pallets (single stack)	11 pal	23 pal	23 pal	30 pal
EUR pallets (double stack)	22 pal	46 pal	46 pal	60 pal
Sea container pallets (SCP) single stack	12 pal	24 pal	24 pal	32 pal
Sea container pallets (SCP) double stack	24 pal	48 pal	48 pal	64 pal

There are two major sizes of containers. The TEU and FEU, they stand for Twenty foot-equivalent-unit and Forty foot-equivalent unit. TEU is 20 foot long. FEU is 40 foot long. There are also variants of these containers. From table 1. you can see the most commonly used containers and their measurements like the dry cargo container (DC), the High cube (HC) and the High cube pallet wide container (HCPW). Basically all three are for dry cargo, this means all types of cargo except liquids. The internal dimension are in key role in determining how many pallets can be fit inside the container. And it is crucial to maximize the fill-rate to decrease logistical costs per pallet. From table 1 it can be seen that with optimal pallet placement a TEU can fit 12 SCP's and by double stacking the pallets double the amount can be fitted. A FEU can fit 24 SCP's and by double stacking 48 SCP's.

Besides the goods and pallets, there can be different kinds of devices placed in the containers. As the time the containers wait for loading in the port, and the voyage at sea can be quite

long, silica bags can be used to prevent moisture accumulating inside the containers and ruining the products inside.

1.13.2 Pallets

Pallet is a transportation device on which the preferred products are placed. Pallets brings stability and shield for the products. Pallets can be easily moved and lifted with a forklift or a front loader and thus increasing handling and warehousing efficiency. The products are usually strapped, stretch wrapped or shrink wrapped on the pallet before moving them to create a kind of one solid element to move. Pallets are usually made of wood, but also plastics, recycled materials and metals are used. (Clarke, 2004.) There is an increasing need for using recycled or plastic pallets as those have more consistent dimensions for automated warehousing systems to run smoothly, they are also safer to handle with no nails or splinters sticking out and there are less particles coming loose from non-wooden pallets. They are also lighter and thus the logistics chain will use less fuel in moving plastic or recycled pallets. Also the leftover plastic material from a company like the case company could be used to produce plastic pallets which would decrease the carbon footprint of the company and making it more environmentally friendly. (Duff, 2022.)

The life cycle of pallets is determined by the intended use of them. A pallet can be single-use, where it is recycled or trashed after just one use. They can also be used multiple times like buy/sell pallets, of which ownership is transferred to whom has it in control. There are also poolable pallets in which case the owner leases the pallets to the party receiving them. Usually in this case the pallets are marked with company insignia or RFID tagged for easier trackability. (Deviatkin et al. 2019.)

According to Deviatkin et al. (2019) The size of the pallets is dependent on what are the requirements of the goods transported and what standards are the stakeholders at the sending and receiving end using. For example in Europe most common type of pallet is the EUR pallet which is 1200mm x 800mm its standardized by the European Pallet Association (EPAL). Whereas markets in China or Finland use commonly pallets with 1200mm x

1000mm dimension. In Finland this pallet size is called the FIN-pallet. There is not a clear global standard for pallets but the International organization for standards has six different standards (ISO. 2020). The height of pallets can vary from 100 to 200mm. (Logistiikan maailma.)

From appendix 1 we can see the required pallet sizes for the suppliers of the case company. The company required its supplier to use debarked and heat treated wood pallets which are up to ISPM 15 standard. The use of Methyl bromide fumigated pallets is forbidden due to its hazardous effect on the environment. All packing materials should be non-toxic and plastics should not contain any PVC. (the company's internal materials.)

There has been some development project to tackle an issue with container fill-rates dropping. In these cases there is sometimes an option to ship products without pallets. But, before the goods are sent to customers they are repacked with other products that the customers are ordering.

1.13.3 Corrugated fibreboard boxes

The company required all its suppliers to use corrugated master- and retail boxes before palletizing the products. The aim of this procedure is to shield the products during transportation and warehousing. This will also ease the task of delivering a certain batch of products to customers as they are readily packed. It is also required to place cardboard on the pallet before palletization, between boxes in the middle of the pallet and on top of the upmost boxes before wrapping the pallet in plastic to add rigidity and give additional protection (Appendix 2).

Retail boxes (RBX) are meant to contain certain amount of products, which is optimized to be a desired amount for the customer to order.

Master Boxes (MBX) are larger transport boxes which are designed to help the warehouse in moving the goods in smaller amounts than full pallets. But in cases there is need to move more than individual RBX's.

1.13.4 Product packaging and product displays

Individual products are packed in appealing and informative product packaging the main function of such packaging is to be appealing to customers, to protect the product and provide necessary information about the product. It is also possible to create product displays. The function of these is that it is possible to place them in a better location in the brick and mortar store so that customers have a better chance of noticing them. A display can contain different products or one type of product.

1.14 Product development steps

The case company is using Stage-gate process in product development. The idea is to evaluate the viability of the new innovations. According to Frishammar, Grönlund & Sjödin (2010, 108) the Stage-gate process has series of gates in which essential processes are carried out. What in these processes is going to be gone through depends on what stage the project is in. First stages aim to bring new opportunities and generating ideas and in later stages the focus is on developing concepts, testing the products, and commercializing. The processes are cross-functional and usually in some extend overlapping to speed up the process. The cost and the commitment of the project is increasingly rising after each step, but also the uncertainties decrease, thus lowering the overall risk. Each gate functions as a stop & go point where the future of the project is decided. The project might need some alterations to pass on to the next gate, it might be halted or even terminated if the viability is estimated to be insufficient. New product development process at the case company has gates from Gate 0 to Gate 5.

The project starts with **gate zero**. Here sales will propose an estimate for the value of the project, finance department will give insight to size and source of the business. The product development team and supply chain teams will both check the business alignment of their responsibility areas. Also it is crucial to map the customer needs, what kind of competition there is, what kind of launch schedule would be realistic. If the project proceeds from gate zero a cross functional team is formed.

In gate 1 the sales and business team will create a commercial concept and the finance team will give estimates for the financial targets for the project. The product development team will create initial concepts for the product and supply chain team proposes a supply chain concept to use in the project. A sourcing strategy will be mapped and the possible supplier will be evaluated if they can produce the concepts within the desired boundaries of the project. In this stage estimate for the product price is calculated and also the financial return including inventories and transition costs.

In gate 2 the purpose is to finalize the design and plans for launch and product plus commitment of external stakeholders. The sales and business team creates Go-to-market plan which means using sales and distributors to provide customer with the unique value proposition the company has to offer. The goal is to increase customer experience with a superior product. The financial department proposes the final monetary goals. The product developers present the final design and the supply chain team the selected supply chain method.

In gate 3 the goal is to finalize the launch plan and sense check the attractiveness of the project. Sales and business teams select the tools for marketing and sales purposes. The financial team gives the sales forecast for the products and checks again the financial return for the product including inventory and transitions. Product development team verifies the product design and the supply chain team checks the capacity requirements and the ramp-up plans. And also orders the zero-run for the product. This means the initial production which is produced in the same way the upcoming mass production will be done. These are not samples any more but should be examples of what the mass production should be.

In gate 4 the idea is to confirm that the production process is valid and to review the zero-run products. Checking that the products match the initial requirements. Also the delivery options are approved. Overall to check if there are any changes to any chapters of the project reflecting previous steps. If all is good then Supply chain will order the first mass production from the supplier and monitors its arrival.

In gate 5 The project will be closed. The Key performance indicators (KPI) will be reviewed reflecting how the project performed. Business and sales teams present the sales performance numbers. Overall reviewing of lessons learned for future improvement opportunities.

1.15 Supply chain at the case company

The company's supply chain aims to perform actions which help achieving customer needs in the most efficient and cost-effective way. The supply chain has significant impact on the company's profitability.

According to the company's internal materials the supply chain consists of the following departments:

1. Sales and operations planning (S&OP) – Makes decisions by approving inventory, demand and supply plans with specific risk and opportunity levels.
2. Demand planning – Builds a consistent plan for what is planned to sell for the desired markets, channels and customers. This is based on the planned sales activities, business offering and sales activities and forecast.
3. Supply planning – The goal is to provide products for the desired stakeholders based on the agreed plans. This is done for short and mid-term for own factories and sourcing partners and it consists of inventory and capacity planning.
4. Sourcing – The goal of sourcing is to identify what do we need, from who do we get it and to build relationships with the suppliers to achieve business objectives.

5. Purchasing – Consists of direct and indirect buying of materials and services according to the supply plans, and monitoring the timely arrival of these.
6. Manufacturing – With global manufacturing guidelines the aim is to harmonize manufacturing activities on different sites to increase productivity, compliance, efficiency and transparency. Manufacturing processes include, the production of finished goods, monitoring and maintaining the equipment, inventory management and shipping to company DC's or to customers.
7. Distribution and warehousing – This department is responsible for storing products at the company DC's and transporting them to customers. The tasks that are done at the warehouse consist of taking goods in stock, storing them and also value added services (VAS) like assembling product displays, engraving products or for example doing the final assembly of the product (like could be done with the case rakes).

The situation with the two case products concerning performance in supply chain has been fluctuating. There are three datasets from beginning of 2020 to November 2022. Monthly line fill percentage, which is telling how many percentages of the customer demand can be filled for each month from. Inventory turnover for every 3 months shows how many times in a year the stock is sold and replaced by new stock. And days on hand shows how many days the current stock will last. We can see correlations between these three datasets on table 2. Concerning the relationship between Line fill and inventory turnover there is a slight positive correlation concerning the large rake and much stronger positive correlation concerning the XXL rake. Between inventory turnover and days on hand there is a slight negative correlation concerning both products. On days on hand and line fill there is a low positive correlation.

Table 2. Correlations between supply chain datasets

Line fill and ITO		ITO and DOS		DOS and line fill	
L rake	XXL rake	L rake	XXL rake	L rake	XXL rake
-0,701	-0,913	-0,695	-0,611	0,399	0,640

This correlation data could be used to pinpoint how much end-product stock is needed to fill the customer demand and how much could be kept as components. This is discussed more thoroughly in chapter 3.

2 Methods

The research consists of a literature review about design for supply chain and logistics. Even though they are different iterations of the same method, in the sake of simplification they will be referring to as one, and there will be best practices used from both. There is also an empiric study conducted about the current processes at the company and key stakeholders. The parties were interviewed to get an understanding on how are things done, what could be improved and if there were any blind spots in current processes.

Based on these a suggestions on how to improve current process of new product development process and a concept design for an improvement for the case product is created. The constructing of the concept design was done using a design research framework from Stone (2010) due to its focus in concept designing. Also SWOT analysis was used to map out different variables related to the products.

2.1 Literature review

The research begins with a literature review in the subject of design for supply chain and logistics. Existing examples of these methods in real cases are explored. The goal is to find relevant cases where DFSC or DFL would be used to enhance the cooperation between product development and supply chain functions.

2.2 Empiric study

Then interviews are conducted as semi structured interviews to give certain amount of freedom for the interviewees. The stakeholders chosen for the interview were picked based on their involvement with DFSC processes and their responsibilities involving the case products or the functions overlapping with design and supply chain. Product design, logistics, supply planning, sourcing, product management, warehousing and package design were selected. The goal was to gather a general idea how these functions portray the idea of

DFSC or DFL and how these themes could help their working and also gather improvement proposals to increase the efficiency of cooperation between design and supply chain.

2.3 Concept design process

Lastly the aim is to search for solution proposals for the possible issues with the case products. And to create calculations to which back these suggestions. How could we approach the issues? According to Stone (2010) the following methods can be used to map the requirements for a concept design.

A market research could be conducted to determine thoroughly what the customers want. This could include demographics, so what kind of numerical data can be drawn from the targeted group. Focus groups could be formed from these demographic groups to discuss and to take note on their reactions and opinions. Also psychographics could be used, so trying to drain why people do what they do. This is done by evaluating their subjective beliefs, opinions and preferences.

An ethnographic research could be set-up. This means a study to find links between culture and human behavior. The goal is to see from individuals as well as group's perspective based on behavior, thoughts and actions. The research can be conducted as an observational research, where there is no interaction with the participants. Or as a visual anthropology where a specialist reviews photos and visual reference material to be able to draw conclusion of the target group.

A user experience research (UX) or usability testing where the product is tested if it matches the needs of the end-user. This allows researchers to directly see behavior towards the product.

For a physical product this can be done in physical lab environment but it can also be conducted as a web analytics test to see how users interact within a certain website. If a real-life target group is hard to come by a Persona test could be conducted. This means creating a hypothetical “perfect customer” from this their motivation, expectations and lifestyle are examined.

Classic Design research is conducted first-hand by the designer. The aim is to get a subjective analysis and visual review on what the customer needs. This can be done by reviewing competing products and reference materials. Prototyping and mock-ups can be used to further refine the design. The designer can also experience the product themselves to gather impressions and insights.

Blended research means combining some or all of the previously mentioned methods. With the time constraint and limited existing research for the subject, the goal in this study is to gather information from internal stakeholders concerning the case products and DFSC. This will also include information from product management which will include information from the customer interface (market research). The plan is also to sketch and 3D-model to foresee upcoming challenges with the product design (Classic design research) and to create SWOT-analysis to understand on broader level the strengths, weaknesses, opportunities and threats to the design. Strengths and weaknesses relate to internal organization and opportunities and threats to the external environment. Strengths and weaknesses are seen as helpful attributes and weaknesses and threats as harmful attributes. (Crowder et al. 2019.)

3 Results & design development

Next the improvement proposals are going to be gone through concerning the transportation of the rakes, the findings from the interviews and the concept designs based on the theory and interviews.

3.1 Large lawn rake and XXL leaf rake

The company uses a robust hardened aluminium shaft with Ergonomic Soft grip handle with the leaf rake and the lawn rake. The rake head is a polypropylene one piece injection moulded component which is attached to the shaft by single screw. The rakes are assembled at the factory and thus they are transported as complete products. This is beneficial for the customer warehouse receiving these and the end user as no pre-assembly is needed before sales or using the rakes. But the shape and size of the rakes makes it difficult to transport them cost-effectively. So there is a lot of empty space left on each pallet and the full length rakes require space which is equivalent to two pallets loaded on top of each other. There is also possibility to load these without a pallet like in figure 8.

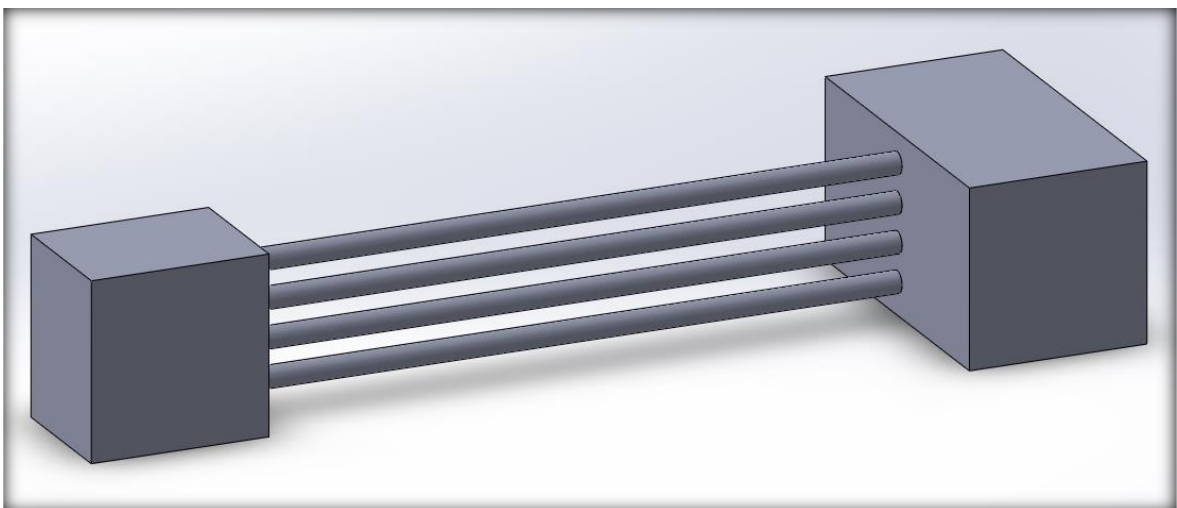


Figure 7. Example how XXL rakes are packed in 4 piece packages with current way. They are transported without pallets from the factory.

The case examples are Large lawn rake and the XXL sized leaf rake. Both rakes use the same shaft only the rake head is of different size (see Table 3 for measurements). There is also a Small rose rake and Medium iron rake and multiple smaller weeding tools in the product range, but in this thesis will be concentrating in the two largest rakes with sizable polymer rake heads and thus most potential for more compact sizing.

Table 3. The case products main dimensions (product dimension from company website)

Product name	Large Lawn Rake	XXL Leaf Rake
Width (mm)	490	615
Length (mm)	1760	1765
Height (mm)	44	46
Weight (g)	800	910

3.2 Solution to research problem

As the research problem stated the issue is that logistics costs have increased massively and the pressure to increase product prices or finding solutions to tackle the issue other ways is urgent.

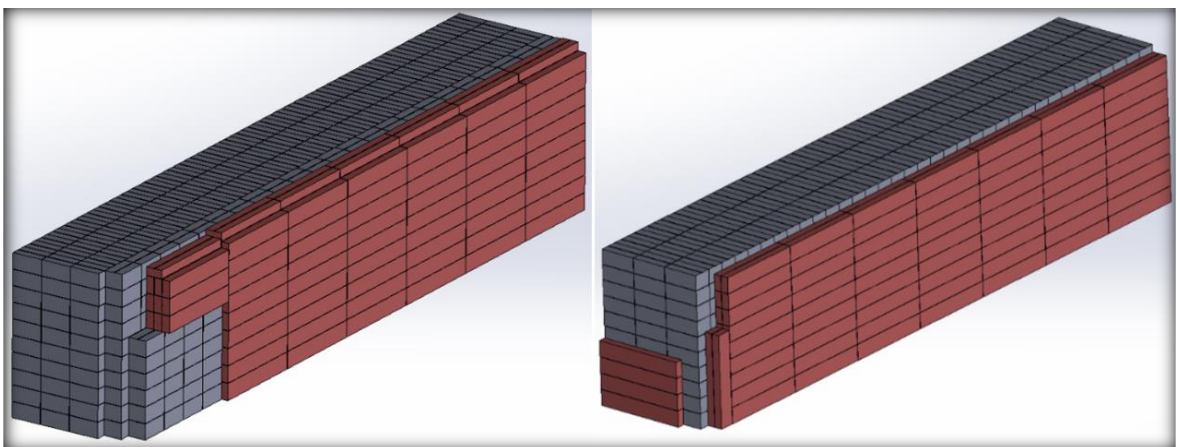


Figure 8. Optimized container fill with rake heads separated. On the left L lawn rake and on the right XXL leaf rakes (grey boxes are rake heads and red boxes the shafts).

One solution could be to ship the rake shafts and rake heads separately and thus fitting from 318 % (XXL) to 356 % (L) (see figure 8) more per 40ft High Cube container than before. Previously one container could fit approximately 1600pcs of L-rakes or 1320pcs of XXL-rakes (see figure 9). But by separating the rake head, one container can fit 5696pcs of L-rake heads and the same amount of shafts or 4200 XXL rake heads and 4224 shafts. Concerning logistical costs per product this means only 28 % (L-rake) or 31 % (XXL-rake) compared to original costs.

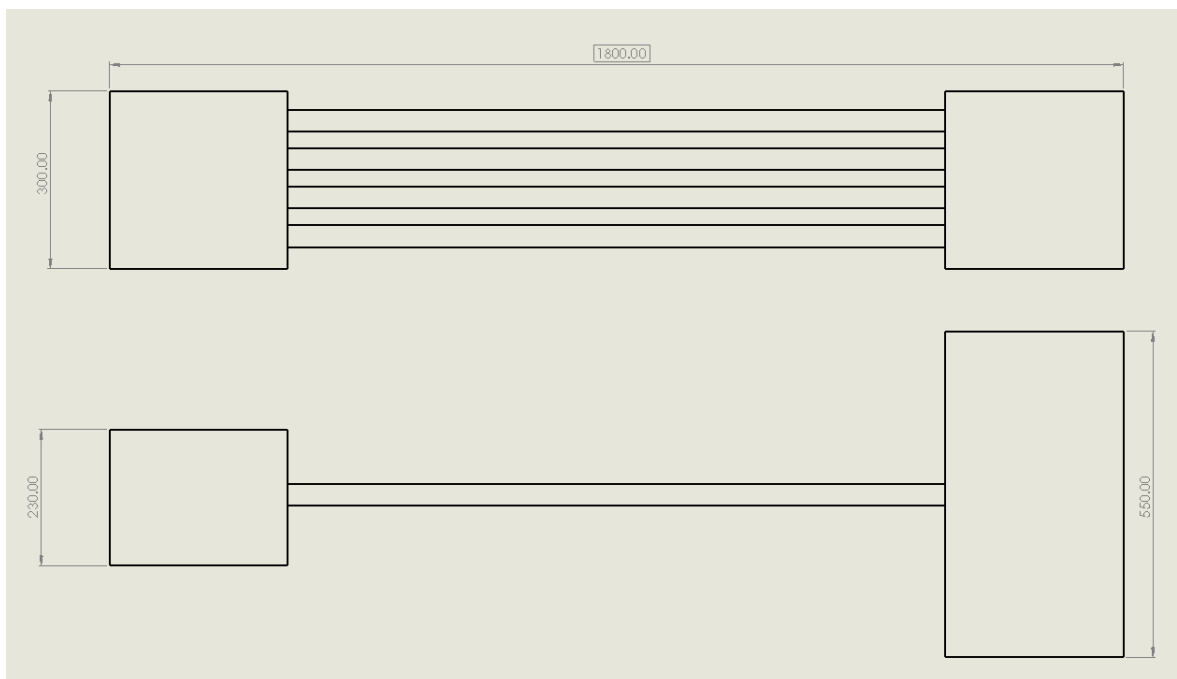


Figure 9. Measurements of the packed XXL rake. One 40 HC container can fit 300 packages of these four packs of rakes.

With this more compact method for filling the container we can also estimate that the CO₂ emissions per product caused by the logistical chain of the container would be reduced by 68,6 to 71,9 %. The first being with a container filled with XXL-rakes and the second with L-rakes.

The final assembly could be done at the case company's distribution centre (DC), at the customers distribution centre before transporting the product in stores or at the end-users

location. As there is also Ecommerce sales channel nowadays the customer can also order the product directly from the company's warehouse and thus skipping the customer DC step entirely (see figure 10).

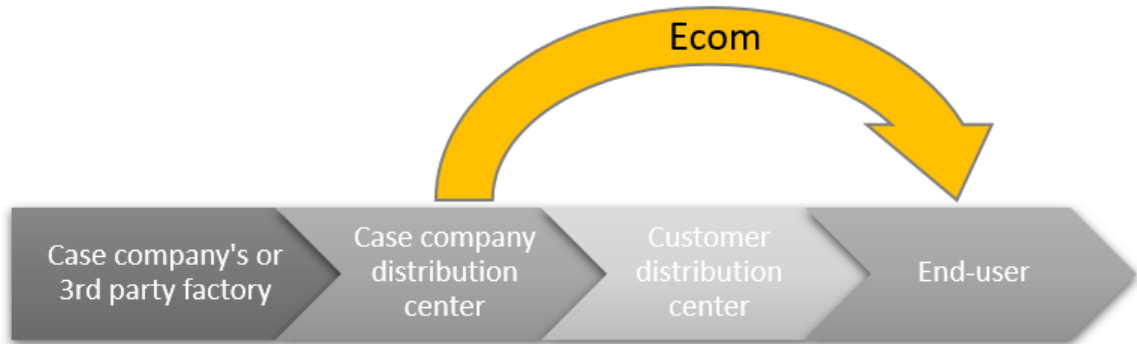


Figure 10. Flow of goods from factory to end-user.

If the assembly would be done before sending the goods to customers, this would mean additional costs at this stage and the labor costs are approximately 1.8-times higher in central Europe and 1.55-times higher in Finland than in China (See table 4).

Table 4. Labour costs concerning different sites. (Trading economics, 2022)

Country	Site description	Labor cost in points
Finland	Regional DC	106.0 (June 2022)
Netherlands	Central DC	126.0 (June 2022)
China	Factory	68.3 (October 2022)

And if the final assembly would be done at the customers warehouse, the case company would probably need to amend price reductions as part of the work would be done by the customer and they would need to facilitate space for this kind of additional work.

If the assembly would be done by the end-user, it could be justified with environmental aspects and concrete numbers on CO² emission reductions and price reductions would not necessarily be needed.

3.3 Empiric research – Semi structured interviews

From table 5 can be seen the different issues risen from different stakeholders, the proposed enhancements for the processes and some aspects that require more research.

The bigger issue that rose from the interviews was the fact that the larger products are difficult and inefficient to transport, warehouse and pack. Also the way some of the key figures are calculated when making decisions should be recalibrated to gain better visibility to the actual costs. Also the gap between supply chain teams and design teams was mentioned. Including the fact that supply chain is taken into the process later and thus there is only little wiggle room to perform optimal solutions concerning supply chain and this can cause extra work for the designers.

As a proposition the detachment and redesign of the rake head and shaft assembly could be considered. Thus reducing the space needed to transport and store them. Also the final assembly could be done in later stage than at the factory. This would add some leeway to keep just the right amount of fully assembled products in stock and the rest as components.

To solve the issue with communication between supply chain and design teams a product owner or similar could be appointed to coordinate the processes between these stakeholders.

Further studying could be done to calculate the exact costs for the assembly done at later stages in the supply chain and the effect on environment. Also investigate better key performance indicators to encourage both supply chain teams and design teams to cooperate already from the start of the NPD project.

Table 5. Conclusion of the interviews and next steps.

Department	Issue	Proposal	Next steps
Supply planning	Inventory turn over, if it's slow with these large products, it means a lot of warehouse space reserved.	Shipping rake head and shaft separately and doing the assembly work at the DC. This means more compact warehousing and not as much inventory needed due to both rakes using the same shaft. In bigger picture, the more the products consumes space the more costly they are to keep in warehouse, therefore it would be wiser to do the final assembly further down the supply chain than at the factory.	How much of a space save would it be? Detailed Inventory turnover calculations to check if it makes sense to have less inventory in more compact form.
Supply category management	Use of median values when calculating the effects of transportation and palletizations on costs	With more accurate numbers the visibility to correct business impact would be visible and "more" correct decisions could be made	Feedback from customers about the possibility to do assembly at their premises or moving it to end-customer.
Sourcing & logistics	Unefficient logistics for the rakes. The size and shape makes it difficult to pack them efficiently. Thus they are usually transported without pallets from the factory.	Possibility to move the assembly to DC's, but also be aware that currently it is more efficient to do assembly at the factory. Possibility to also optimize container fillings with more efficient purchasing (amounts based on container and pallet sizes).	How much is the cost savings from logistics vs. the cost of factory assembly compared to DC assembly.
Warehouse (DC)	Products arriving poorly palleted or damaged. Difficulties processing web orders for large products.	Move the assembly job to RDC. By receiving rakes as components they require less space.	Investigate the actual cost impact of the assembly work and the time it takes to complete it. Continue studying the issue related to Ecom orders of large products.
Product design	Product design and SC should maybe be involved earlier in the design process to get most benefit for both parties. As the later it happens more difficult the changes are.	Maybe some unified bonus metrics could also help the interaction. There could also be a "product" owner coordinating the processes between both parties.	What KPI:s do these parties now have in place? Could those be adjusted to cover DFSC aspects as well?
Packing design	The early improvements for logistics that are hidden inside the design process. Current logistical optimization tools quite heavy to use, thus simpler tools in use. There isn't a dedicated person to handle the interface between NPD and SC	By documenting them early on, it would be possible to see how far the design is improved and the benefit concerning DFSC. Is it possible to switch to lighter but well performing tools. Maybe expand some current employee responsibilities or hire a new person.	Issues with products that can not fit on pallets. Designing a tool to tackle this issues.
Product management	The possibility of the customer doing the assembly not really discussed, but the assumption is that the reception is not positive.	Maybe explore the opportunity to direct the assembly for the end-user instead of the customer warehouse. Thus preventing any extra costs for the customer warehouse.	Concrete numbers on what the effects would be concerning costs and environment.

3.4 Concept design

As seen from chapter 3.1 and from the interviews there are certain aspects on the case rakes that could be redesigned to improve the logistical efficiency of the products. Mainly the overall size and shape are an issue for current ways of transporting them. As presented with any proposals we need to keep in mind that it might not be the most cost efficient way to do things as the logistical costs are fluctuating based on different disruptors of given time scope. As discussed in chapters 1.3 and 1.4 today it is Covid-19 and the war in Ukraine and as an indirect effect inflation and increasing energy prices, but in another time it can be something else.

On figure 11 a SWOT analysis concerning the rake design improvement is presented. With this tool we can explore different factors affecting the matter at hand. Strengths and weaknesses are from internal aspects and opportunities and threats concern the factors from outside the organization.

By implementing DFSC for NPD processes it is possible to find completely new innovations from the interface between supply chain and NPD. On the weaknesses side we have the current poor transportability, quite high value-added-services costs which means the assembly work done in DC's and also the possible demand cannibalization from other product categories if the changes made make the current products too similar in functionality and in the eyes of the customers.

For external opportunities, it is possible to achieve emission savings by increasing the container and pallet fill-rates and thus requiring fewer trips to receive the same amount of products. It is also possible to increase the competitive advantage with more efficient supply chain by increasing reliability in the eyes of the customers and possible achieve better cost efficiency. The a threat can be seen the competing products as the development is continuing also for the competitors and there can be a break for DFSC also for them. Also the rising production costs are chewing away profit margins and combining current issues with supply

chain costs and inflation it can become increasingly more relevant to source closer to current markets.

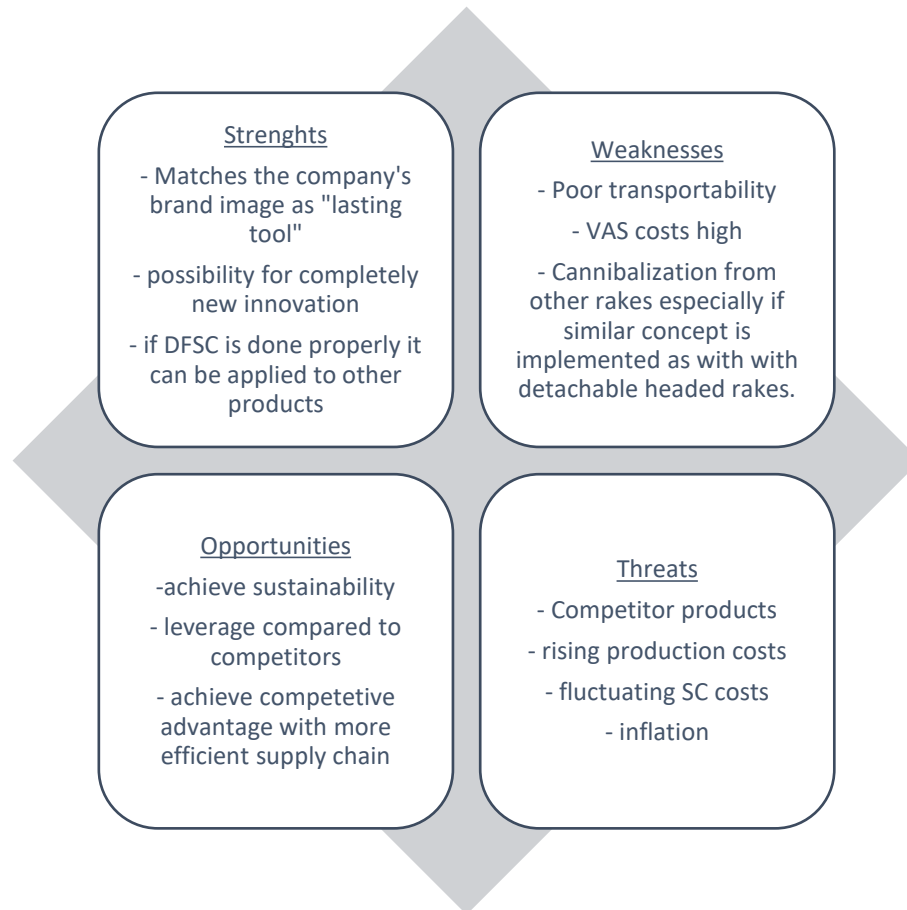


Figure 11. SWOT analysis for the L and XXL rake's design improvement.

Keeping in mind the risen pain points in the interviews, the design alterations proposed in the thesis are: making the shaft more compact and making the rake head easily attachable. By making these alteration a significant size reduction can be achieved concerning both packaging and transportation and warehousing. These relate directly to the SWOT analysis' sustainability, better transportability and leverage to competitors aspects.

The shortening of the shaft could be achieved with a telescopic structure. The benefit with this solution besides logistics is that it would suit users of different heights as it could be easily adjusted. This issue was raised when interviewing the product design team. In this design the telescopic feature is achieved with a push pin. An alternative to this could be a

telescope mechanism with an internal twist locking mechanism. This would mean a stepless adjustment rather than adjustment between specific pin holes meaning more tailored feel. It could also be considered that by implementing the telescopic shaft the rake head could be kept attached as it could be fitted even with the rake head on a pallet. This would eliminate any assembly work needed from RDC or the customers. This feature would eliminate a good portion of the transportation issues and VAS costs mentioned in the SWOT analysis.

Another solution could be a two part shaft with a snap on closure without the telescopic feature (figure 12). The issue with the snap closure might be the additional joint in the middle of the shaft which affects the structural strength compared to solid one piece construction. But the manufacturing costs would be lower than with telescopic shaft. Also by splitting the shaft the rake could be fitted on a standard pallet.

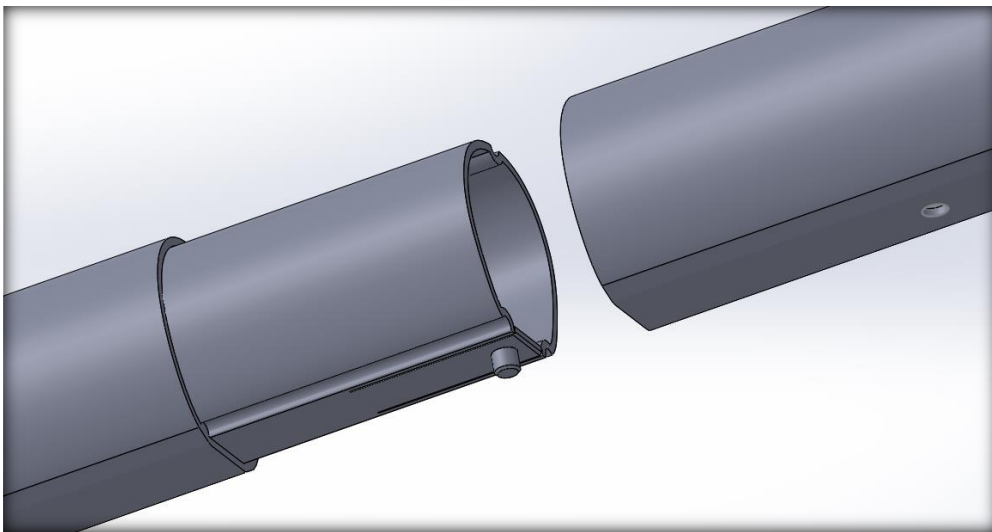


Figure 12. Concept design for the snap closure mechanics of two part shaft.

There was also consideration about a solution which enables the transportation of the shaft in two pieces but the assembly could be done only once. So a permanent connection making it essentially a solid one piece shaft. Here we could use similar solution as with bicycle steerer tube assembly by using a star-fangled nut as seen on figure 13. The benefit with this is that in not so many cases there is a real need to take the rake apart after the end-user receives it. In many cases there is enough space for storing full length rakes at the premises

of use. This would be quite unique solution and different compared to competitors and checks boxes from the SWOT analysis' strengths and opportunities.

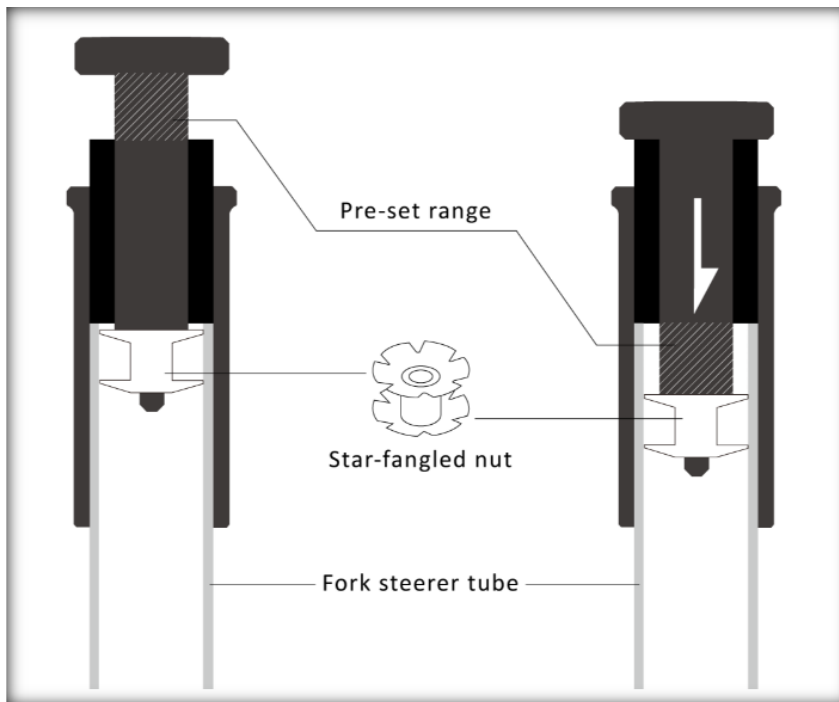


Figure 7. Bicycle steerer tube assembly (in this case the fork steerer tube imitates the lower half of the rake and the dark grey the upper half of the shaft)

The rake head's attachment could be executed quite straight forwardly as there already is a hole for a screw. That could be replaced with a snap closure system, like the one on figure 14. With this, the assembly work could be done much faster and without tools, compared to screw attachment.

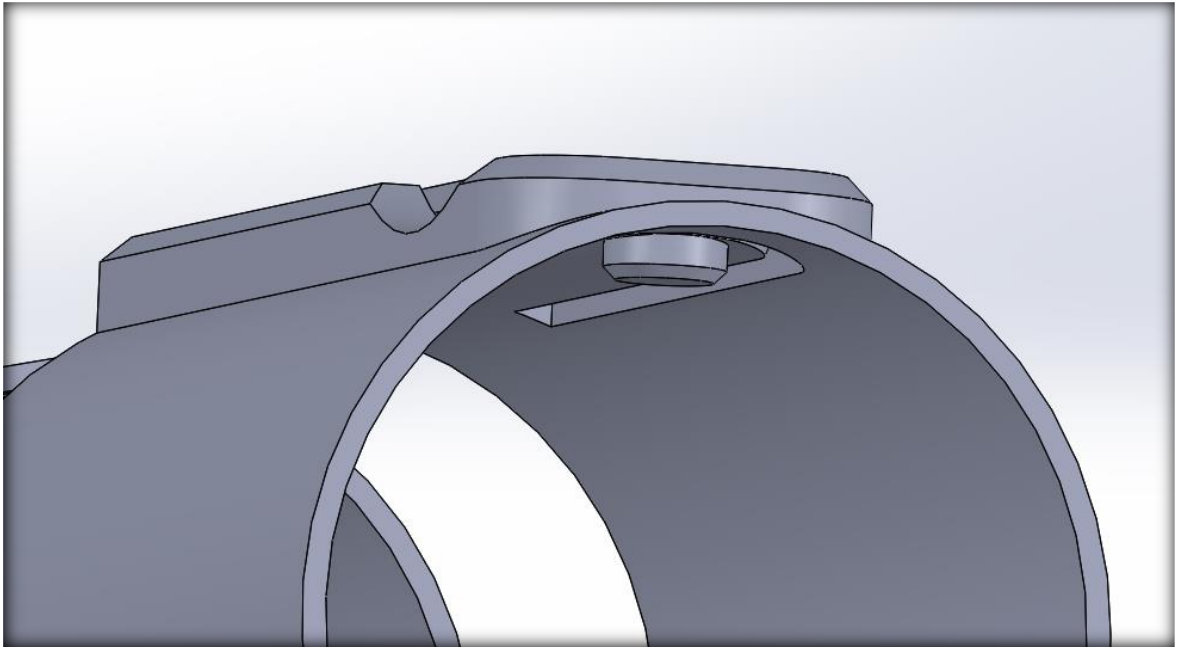


Figure 14. Rake head attachment by combining snap closure to the rake head (rake head is “cut off” to demonstrate the push pin location)

The snap closing feature could also be implemented directly to the rake head, so that it would be added to the injection mould of the rake head, and thus not needing a separate component and an additional assembly phase. This solution is shown on 3D model on figure 15 and 16. Another benefit with this is that the snap closure is shielded and thus can't be accidentally activated. You need to lift the highlighted blue lever up to remove the rake head from the shaft. It has cut-outs for ease of access with two fingers. With this solution production costs could be lowered concerning the assembly phase and component costs concerning external push pin solution.

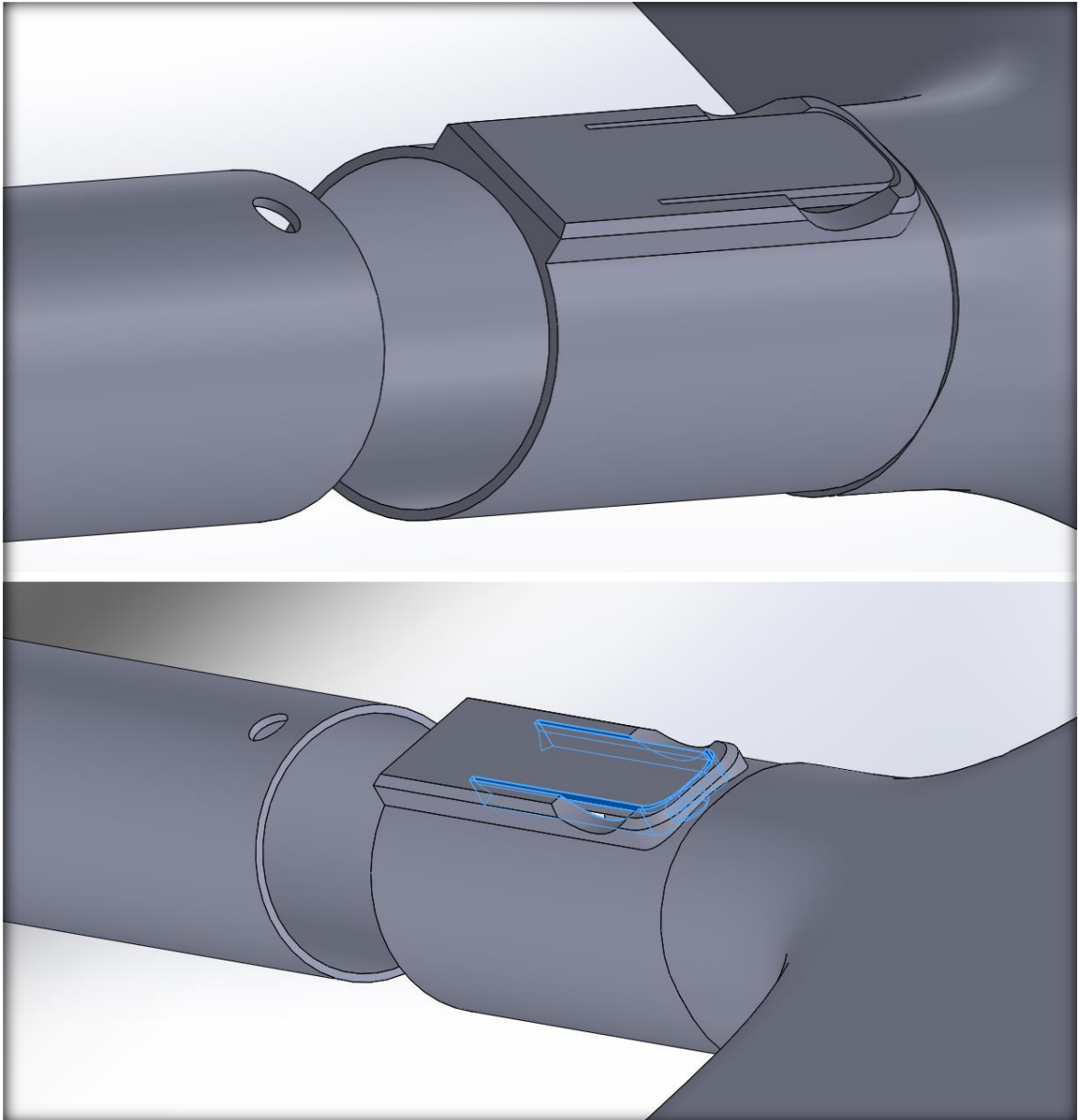


Figure 15. Rake head attachment by combining snap closure to the rake head. The rake head and the closing mechanism are manufactured simultaneously with injection moulding.

To be able to manufacture the rake head with the locking mechanism, current mould needs to be altered and probably an additional slider feature to be added due to the undercut nature of the locking feature. This would mean increased tool costs.

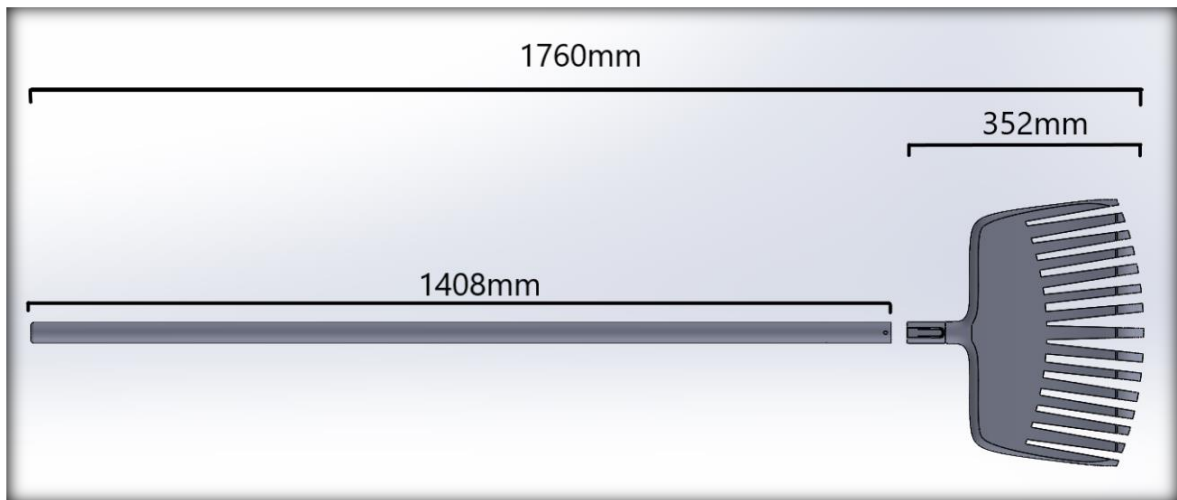


Figure 16. Illustration with measurements of the detachable rake head and shaft

The concepts designing was first done by doing some rapid sketched and then translating these ideas to 3D-models in Solidworks and continuing the iterative improvement of the ideas there.

3.5 Process improvements

The current gates process could benefit from a process owner for DFSC aspects as based on the interviews many of those aspect are in a risk of getting too little attention. With a dedicated person the responsibility and the point of contact would be clear.

This person could have specific check points during the gates meeting to keep everyone on same page concerning DFSC. I would base these check point on the theory from HP's case and the case by Dowlatshahi, 1999. A one-pager could also be presented for everyone involved in the NPD process, to highlight the benefits provided by DFSC (See figure 17).

For people who are not familiar with DFSC, it is good to underline the key elements and benefits from the method. With goals to highlight the benefits, the success criteria tells how well the implementation went. The backstory widens the benefits and tells in wider scale why this is important. The Mandatory tells what is required to be able to achieve the benefits.

The out-of-scope tells what is not included in the method. Threats tells the easy risks which can affect the outcome. The key timing elements are telling when to use the method or when it can be the most beneficial.

DFSC one-pager

- **Goal**
 - Lowering overall costs by using cross-functional teams in NPD projects
- **Success criteria**
 - Supply chain risk reduction
 - Overall cost improvement
 - Better cooperation between departments
- **Backstory**
 - Decisions made in the design process fix many paths for supply chain and other functions to take next. Also ruling out possibly the most optimal solutions.
- **Mandatory**
 - Mutual goals and metrics to follow
 - Involvement of the department heads
- **Out-of-scope**
 - Not purely cost cutting process.
- **Threats**
 - Too hasty schedules
 - Pressure from line managers
 - Siloing of different functions
- **Key timing elements**
 - Rapidly fluctuating logistical costs in the market
 - Rising supply chain risks
 - When launching n innovation

Figure 17. DFSC one-pager for internal stakeholders at the case company.

4 Analysis & discussion

Based on the data in the latest supply chain pressure index in chapter 1.4. It could be considered to include a check point in the Gates process to review what is the situation of global supply chain pressure index and if there is a need to implement higher risk factor based on the level. Similar thing concerning container prices. If they are highly fluctuating, there could be a factor to take into account the higher container prices and maybe even consider sourcing the products closer to reduce logistical costs. There also needs to be consideration that by implementing DFSC practices, it is possible to reduce the logistical cost per product and thus mitigating the effect of higher logistical costs of containers.

Major aspect that was pointed out both in the literature review and the interviews was that after the product design is completed it can be difficult to find an optimal supply chain solution at that point. And making changes to the design in this stage, based on supply chains requirements, is very cost inefficient. Also in the literature it was pointed out that the financial incentives are not usually congruent with design and supply chain departments. This can create insufficient cooperation between the departments and end up creating both poorer performing supply chains and the products moving inside the chains. As a solution to this it was suggested to possible extend some current role or to get a dedicated person to be a “product owner” concerning the interface between product development and supply chain. This person could be involved all the way from beginning of Gate 0 to have a clear view on all the changes to the design and the improvements. Also concerning the calculations concerning logistical costs, there has been an issues when using median values, but this person could take the ownership of exact calculations to gain clear visibility on the measurable aspects.

Based on the interviews multiple departments agreed that the current way of assembling and transporting the case products is not optimal. There were points in favor of moving the assembly work further down the supply chain and thus using postponement to delay the assembly work, but it was not 100 % agreed to which DC or even the customer. According

to RDC the rakes would take less space as components and thus reduce the needed warehouse capacity. Most were agreeing that the assembly should be done at RDC, but there were also suggestions for customer warehouse or even the end-user. But these options would require additional investigation, sparring with the clients and clear assurances for the customer on why this would be smart thing to do.

Based on the data on how many rakes can fit a 40 HC container with the current way and the optimized way, with rake head and shaft detached. It is clear that concerning pure container space saving, it is considerable with the latter method. But we can not only focus on container fill-rate as the detached method requires additional work in later stages of the supply chain, but so does the method when they are transported in one piece.

In the concept design phase we explored different solutions for compacting the rake. We already had calculation for the possibility to detach the rake head and shaft but there is also the possibility to create a telescopic shaft and still keep the rake head attached. This would eliminate the poor transportability and the need for assembly work further down the supply chain. We also explored an improved snap closure system, compared to current concept for the rake head, where it would be fused in the rake head and thus needed no extra components or assembly phase.

The findings from the thesis could be difficult to generalize due to the case product being such specific, but in the case company's other internal processes these could be possible to apply. It also has heavy emphasize on interviews and those reflect the views of individuals based on the issues they deem noteworthy. Also concerning the concept design phase, the writer has taken some liberties to explore product improvements on the aspects based on the theory and interviews.

All in all DFSC could be implemented in any organization, but the issues are not necessarily similar as with the case company. Thus if this thesis would be used in other organizations

there should be emphasize on the theory part not necessarily on the findings from the interviews or the concept design.

5 Conclusions

By implementing DFSC practises there could be many benefits achieved at the case company. Especially with larger products. With the case products by detaching the rake head from the shaft there is a possibility to fit a container with 318 to 356 % more products and the CO² reductions based on the container fill-rate is reduced by 68.6 to 71.9 % per products. Concerning logistical costs per product the drop would be from 28 to 31 %. Of course these calculations needs to be matched with the actual costs that would occur by assembling the rakes further down the supply chain to have a clear view what the actual savings would be.

In bigger picture the cooperation between different departments is crucial to achieve most efficient outcome for the new product development project at hand. DFSC can be a useful tool to achieve this goal. It needs some additional focus to break the silos of current departments and create mutual incentives.

Concerning the impact of this research, it could be used as a stepping stone to further the goals of both product development and supply chain. Even though the products considered in the thesis were specified, the general theory remains the same for other products as well.

To further study the benefits of DFSC there should be given a chance to test the theory in practice, even if not in full scale, challenging current ways of working can be beneficial to spark new ideas for the whole organization. A further study could be needed to investigate if the better transportability is a big enough argument to change the current design so drastically that the design would be resembling other case company's designs and thus risking of cannibalization customer demand from other products. Also a break even analysis should be conducted on when it is more beneficial to make products more compact rather than transporting full length items with non-optimally filled containers and pallets.

6 Summary

In this thesis product development processes named Design for supply chain (DFSC) and design for logistic (DFL) are covered. They both focus in combining product development with logistics and supply chain improvement. These aspects have become increasingly important due to drastically increased supply chain costs, supply chain risks and overall global market instability. They can have major impact on companies profitability and viability if not taken into consideration properly.

The goal of the thesis is to map how these methods could be used at the case company's new product development processes, what kind of issues are there currently and would DFSC provide solutions to these.

The thesis was conducted with a literature review on the subjects of DFSC and DFL. Also to map the internal stakeholders semi-structured interviews were conducted and lastly based on the data from the research, concept designs were proposed and suggestions to improve the current process.

The surfaced issues were related to larger products moving inside the supply chain, but also to the current new product development processes where the coworking of designers and supply chain teams should be improved to gain better results concerning both stakeholders.

As a result a concept design based on DFSC principles was created for the case products to stir new ideas and to highlight the benefits of the process improvement method.

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4.10.2022 interview with supply category management. MS Teams

18.10.2022 discussion with product manager for rakes. MS Teams

18.10.2022 session with sourcing. F2F & MS Teams

20.10.2022 interview with supply planning management. F2F

26.10.2022 discussion with packaging design team. MS Teams

31.10.2022 discussion with Regional distribution center (RDC). MS Teams

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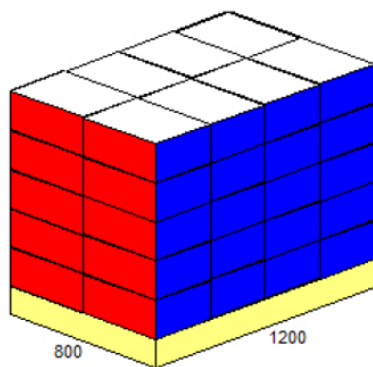
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Appendix 1. Pallet sizes used in European land transports and overseas sea containers by the case company (The case company's internal material).

EURO pallet 1200x800x144 mm

(used in land transportation in Europe)

**Maximum height of unit load
1200 mm**



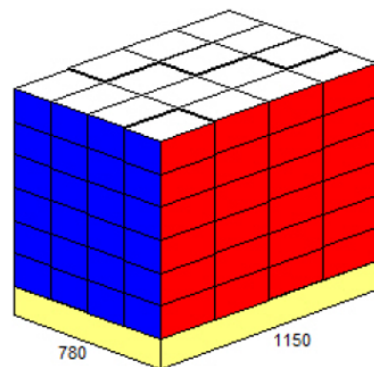
Sea container pallet to EMEA;

1150x780x144 mm

or

1150x800x144 mm

**Maximum height of unit load
1150 mm**



Appendix 2. Palletization of Master boxes on pallet and wrapping at the case company's distribution center (The case company's internal material).

