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Improving global supply chain performance from an SME perspective

MASTER'S THESIS

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ABSTRACT

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The purpose of this research is to search out ways to improve the global supply chain performance for the case product. The research uses qualitative single case study method, where the phenomenon is examined from the case company perspective. Furthermore, the empirical data consists of semi-structured interviews, survey and company data provided by the case organization. Alongside the empirical study the research uses theoretical literature from various academic journals and articles to provide extensive information of the previous studies and literature about the topic. Some of the main themes in the literature review are the supply chain management, lead time management and lean supply chain. The results of the study reveal that the main issue in the supply chain performance was the poor supplier capability. Additionally, lots of excessive time was detected in the supply chain processes, and because of the high product complexity and lack of resources the supply chain lead time was longer than the company desired. By having more efficient suppliers and understanding the entire supply chain processes better, also higher results and customer satisfaction can be expected in the future.

TIIVISTELMÄ

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Tämän tutkimuksen tarkoituksena on löytää keinoja globaalin toimitusketjun kehittämiseksi case-tuotteen osalta. Tutkimuksessa käytetään laadullista case-tutkimusmenetelmää, jossa tutkittavaa aihetta käsitellään kohdeyrityksen näkökulmasta. Työn empiirinen aineisto koostuu puolistrukturoiduista haastatteluista, kyselystä, sekä case-organisaation materiaaleista. Lisäksi työn empiirisen osan rinnalla käytetään teoriakirjallisuutta, mikä koostuu useista akateemista lehdistä, artikkeleista ja kirjallisuudesta, antaen syvällisempää kuvaa aikaisemmista tutkimuksista sekä kirjallisuudesta aiheen tiimoilta. Kirjallisuuskatsauksessa käsitellään pääasiallisesti toimitusketjun johtamista, läpimenoaikojen hallinta, sekä Lean ajattelua. Tutkimuksen tulokset osoittavat, että toimitusketjun pääongelmana nähtiin olevan erään case-yrityksen toimittajan heikko suorituskyky. Lisäksi toimitusketjussa havaittiin olevan paljon ylimääräistä ”hukka” aikaa. Lisäksi tuotteen monimutkaisuus sekä case-yrityksen resurssien vajaus nähtiin olevan toimitusketjun tehokkuuden kannalta merkittävässä roolissa. Valitsemalla valmiuksiltaan tehokkaampia toimittajia, sekä ymmärtämällä kokonaisvaltaisesti toimitusketjuprosessit ja sen kriittiset vaiheet voidaan tulevaisuudessa odottaa myös parempia tuloksia niin läpimenoaikojen kuin asiakastyytyväisyydenkin kannalta.

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During these years at the university I've had many unforgettable moments and memories that I will never forget. Now it is time to take the next step in life and continue the lifelong journey with an open mind. This research process has taught me a lot about the life and I will definitely stay curious for the future challenges and opportunities.

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Vantaa, 1.8.2018

Antti Kokkola

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1 INTRODUCTION

Globalization has changed dramatically the way most of the companies operate in today's world. The global integration brings both new opportunities and challenges for firms that do business both in domestic and global markets. In the integrated world, the flow of physical goods, services and information are being transferred faster than ever before. Outsourcing business functions and purchasing components and raw materials from other side of the world is everyday life in the modern society. This development has also touched the supply chain processes, that almost every company has in some level. According to Dittmann (2014) the supply chain is exposed to most of the firm's risks, due to the global features and systematic impact on the companies' financial performance. This also increases the need for diligent supply chain management practices by the companies around the world. Efficiency is one of the key principles in the supply chain regime and to achieve the desired targets companies have to coordinate and improve every link in the supply chain in order to have the best possible results.

The increased demand for well-organized supply chain activities keeps on growing, because companies are more focusing on their core competences and outsourcing the non-core activities to the third-party providers. Components and services can be sourced from other side of the world and the delivery times for those acquisitions can be only few days long. The current nature of supply chain has also changed from traditional chain perspective to more complex network view. Satuli (2016, 28) points out that the traditional supply chain is now being replaced by more dynamic and integrated networks. Furthermore, companies are not competing against each other, but the competition is now between extended supply chains (Lamber and Cooper, 2000). This indeed is the direction we are going. Today, complex supply chain incorporates various actors across the globe and the key is to manage these different actors in the supply chain system in the most efficient way.

As the competition keeps increasing, the key for success is to satisfy the changing customer needs. Usually these needs are fulfilled when the product or service creates maximum value with the lowest possible costs. To accomplish this, companies have to form and manage the supply chain activities with maximal efficiency and lowest possible operational costs. In the era of digitalization, these results can be achieved much easier than few decades ago. The future direction of supply chain management and logistics can't be predicted, but it is clear that current contemporary topics like IoT (Internet of Things), blockchain and robotics are changing the way firms approach these complex business networks. Yet, it can be almost impossible to give common advices for different companies about how they should improve their current supply chain performance, because every single supply chain is unique in its own way. Therefore, firms must understand the interconnections with other parties in the supply chain network in order to maximize the long-term value for every company and customer in the supply chain web.

1.1 Background of the study

Undeniably, well organized supply chain activities are strategic asset for the companies. From the 1990s started global integration and increased competition between companies created a significant gap for the supply chain management practice that is now seen as a major competitive weapon in response to the global competition (Li, Ragu-Nathan, Ragu-Nathan & Rao, 2006, 107). Today, time is more valuable than ever before. Managing the time, especially in the supply chain context is highly important, because customers along the supply chain anticipate precise schedules for their deliveries and some late shipment can result in challenging situations for the clients and all the way up to the end users. Branch (2009) mentions that a fundamental aspect of the current global supply chain environment is the reduction of the total lead time of the entire supply chain activities, from order to the delivery. Thus, the increased need for high-performance supply chain operations keeps on growing.

Naturally, the supply chain management is also highly connected with the company costs. Myerson (2012, 6) mention that supply chain costs typically range from 50 to 80 percent of the costs of sales making it a major contributor to the total costs. These costs are included in every single node and activity in the supply chain, from order processing to the delivery of the final product. These activities are purchasing, delivery, manufacturing and warehousing just to mention a few. According to Christopher and Towill (2001) the improvement of the supply chain performance can be done by reducing costs and increasing the customer satisfaction at the same time. The goal is to service the customers at the level they are demanding, and the supply chain costs can be modified according to that service (Brewer & Speh, 2000, 80). Meaning, that if the customer prefers a fast and customized delivery by airplane, it creates some extra costs to the supply chain and thus the unit price can be higher, whereas the other customer that expect only regular shipment, the delivery time can be longer and thus the delivery costs are expected to be lower.

To increase the supply chain performance, many companies are applying the lean concept to reduce the waste and improve the efficiency of the total supply chain activities. By properly adapting the lean mentality companies can reduce waste, errors, unnecessary assets and improve lead times by constantly aiming for perfection throughout the entire supply chain network (Morash, 2001, 38). Now, when the domestic markets are facing the global competition, companies are increasingly facing new challenges. Thus, streamlining the supply chain network, constantly improving internal processes, meeting the customer requirements and reducing the lead times are highly important questions for companies to be monitored.

As the main objective of the study is to investigate how global supply chain performance can be improved from an SME perspective, it can also offer some relevant information for other companies especially in the same industry that the case company operates. Despite of the multi-dimensional environment of the supply chain performance, the study focuses on the lead time reduction and how this could be done in the lowest possible costs. The research offers a topical overview of the supply chain performance improvement solutions, creating interesting information especially for managers in the operational and supply chain fields. As the global complexity increases, the need for efficient supply chain activities keeps increasing and the demand for relevant knowledge especially on how the SME companies can improve the global supply chain performance will most likely thrive in the future.

1.2 Research objectives and questions

Reflecting to the background of the study, the main objective of this research is to search ways to increase global supply chain performance for the case company F, and more specifically improve the performance for the case product. The company manufactures mainly valves, pumps and other systems for demanding process conditions across the globe. The demand for the research originates from the company. The baseline situation for the study was to find out ways to improve the supply chain performance for the case product that the company is currently launching to the global markets. The company launched the case product; Packed Pumping Systems (PPS) to the USA markets in the 2017, but the long lead times in the supply chain were seen to be one of the biggest issues for the company, that needs to be improved.

For the main issue, the research aims to investigate the current situation of the supply chain operations by creating a value stream map for the case product. The purpose of the study is to identify and reduce the bottlenecks in global supply chain system, stream-line the supply chain processes, and also do all of this with the lowest possible costs.

According to Stuart et al. (2002, 420) the primary stage of the research process involves the determining the research question. In this study, there is going to be a one main research question and three sub-questions. These sub-questions are formulated in order to help finding the answer for the main research question. The main research question is:

"How the global supply chain performance can be improved for the case product?"

The sub-questions of the research are:

"What is the current level of the supply chain operations in the case company?"

"What factors affect to the supply chain lead time?"

"How the lean methodology can impact to the supply chain performance?"

The study aims to find the answers for the research questions by using both theoretical literature from the academic journals and books, and also empirical information provided by the case company F. By combining these different materials and resources, and also providing the researcher's own reflection to the study, the objectives of the research can be achieved.

1.3 Research methodology and data collection

This study was conducted by using the qualitative single-case research methodology. The empirical data of the study was based on the real-life company material provided by the case company. Denzin and Lincoln (2008, 4) define the qualitative research as a study that aims to understand different real-life phenomena or situations in terms of the meaning the people bring to them. In addition, Gillham (2000,10) claims that the greatest strength of qualitative research method is that it can bring up issues of certain matters and adduce possible solutions for these issues. Thus, this qualitative research method can be seen really useful for deepening the understanding of the constantly changing real-life situations that the case studies are usually about.

Most qualitative studies can be characterized as case studies. The aim of these studies is to investigate and collect the data in many different ways to gain profound understanding of the phenomenon that has been investigated. (Metsämuuronen, 2006, 91-92) According to Feagin et al. (1991, 2) case studies are not easily categorised into single slot, and these studies can use both qualitative and quantitative data from various data sources. Consequently, the research process is ongoing cycle, that can change and have different type data along the process. Metsämuuronen (2006, 92) also claims that usually when using the qualitative case study method, the intention is not to generalise the results in other similar situations rather to understand the case in question. Thus, single case studies can provide especially meaningful results for case companies and situations that the study is focusing on.

The primary data for the thesis was collected by using the company data-bases, documents and doing observations. In addition, to fully understand the case situation secondary data was collected by interviewing two employees and making a survey to gain better understanding of the processes and operations that the supply chain involves. By combining these different resources, the overall understanding and analysis of the case situation can be made more profoundly. In addition, the study used also both numerical and non-numerical data to have the best possible overview of the situation being examined.

1.4 Research structure and limitations

The research will be structured in the following way. This thesis includes four main chapters altogether. After the first introduction chapter, follows the theoretical part in the second chapter. In this part, the main theoretical background of the study will be presented and discussed. Because of the main objectives and aims of the study the main theory will focus mainly on the global supply chain, lead time management and supply chain performance questions.

After the theoretical part, follows the empirical part in the third main chapter. In this third section, the case study is presented, and main findings of the research analysed. The empirical part includes single case study that uses data provided by the Finnish manufacturing company F. In addition, at the end of this third main chapter, the empirical findings will be presented and discussed in more detail. Finally, after these empirical results both the study conclusions and discussed are presented in the fourth main chapter. Below, the structure of the thesis is illustrated in the figure form.

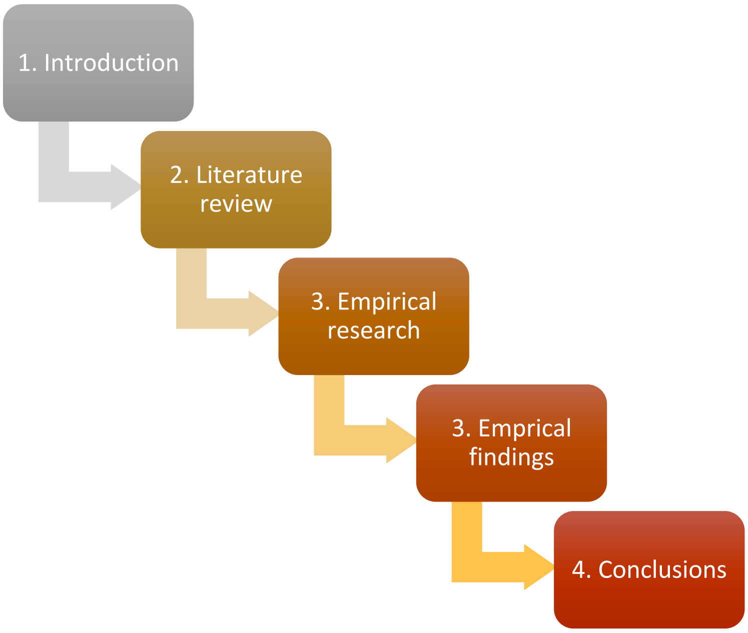


Figure 1. Structure of the thesis

Like in all research, there are some limitations that should be considered. One limitation of the thesis is that the study is conducted as a single case study, which creates some limitations for the reliability and generalisability of the research. Thus, the results of the study cannot be utilized in more general level or context of supply chain management. Another limitation of the study is that it focuses the main topic of the study from an SME perspective. In addition, the study focuses on the supply chain form the case company perspective and the focus is targeted to the supply chain performance improvement (time and costs) and for that reason the sourcing side is limited out of the scope. Additionally, the study is limited to concern only one product (Packaged Pumping Systems) and the special features of the case product can limit the generalisability of the research for the other products in the same industry.

1.5 Definitions and key concepts

In this part of the study, we are going to go through briefly the main definitions and concepts that the thesis entails. Other parts of the study will discuss more extensively the concepts and definitions discussed below.

Supply Chain Management (SCM)

According to Lambert, et al. (1998, 1) supply chain management is the integrated formation of key business processes from end user to end suppliers that offer products, services and information that add value for customers and other stakeholders. Furthermore, the definition relates to the flow of information, goods and capital in the entire network that is formed by the customers, suppliers, manufacturers and distribution companies (Sakki, 2014). Additionally, Zimmer (2002, 1) mentions that the supply chain management can be seen as an extension for the traditional logistics which deals with the different logistics processes in the external supply chain. In the figure 2 below, the different links and processes of the supply chain management are illustrated in the figure form.

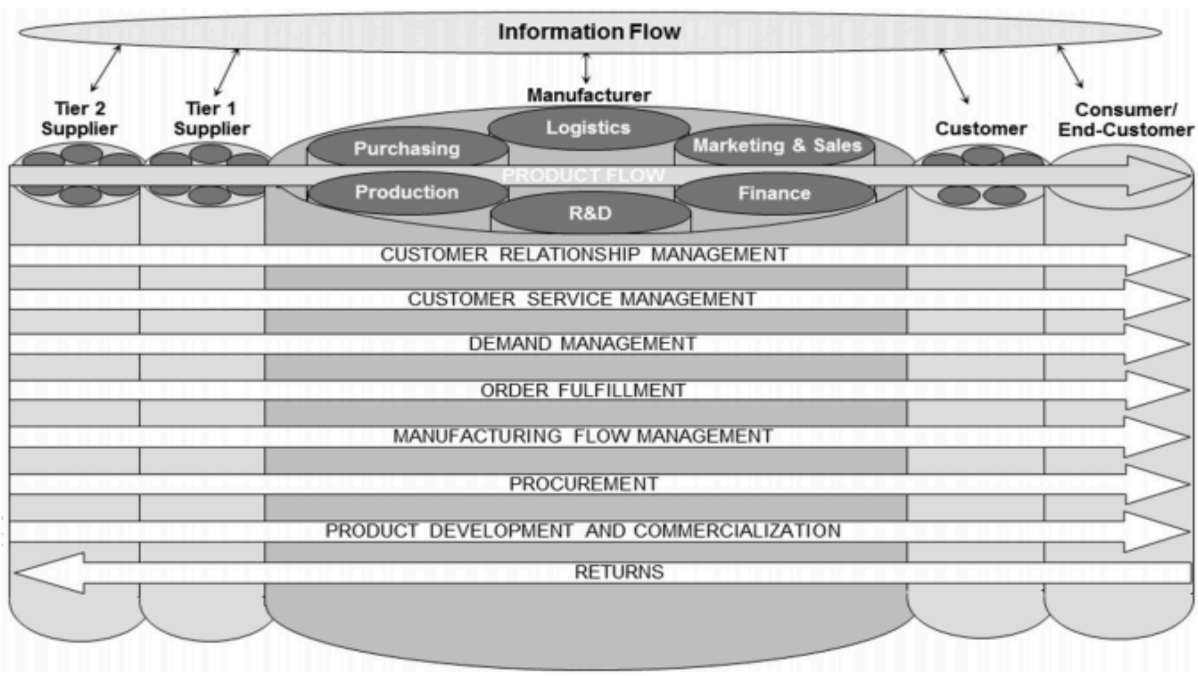


Figure 2. Supply chain management processes (Adapted from Lambert & Cooper, 2000, 67)

Lean Supply Chain (LSC)

Lean in itself, refers to the company-wide “waste” eliminating process that aims to reduce waste from the processes in a continuous manner (Myerson, 2012, 2). The terms lean supply, lean supply chain and lean supply chain management don’t have a one comprehensive meaning and different authors tend to have a bit different definition about the concept. According to Lamming (1996, 187) the lean supply is an operational approach that aims to maximize the long-term customer value by identifying and reducing the total costs in the processes. Branch (2009, 27) on the other hand, defines the lean supply chain management as a strategic process that aims to satisfy the end user needs by managing the supply chain processes in a cost-effective and effectively way in the global context. In conclusion, the lean supply chain aims to reduce the waste and minimize the costs of the whole supply chain activities to satisfy the end user needs and at the same time constantly strive to improve the current processes.

Lead Time

According to Heydari, et al. (2016, 215) the lead time is the time period between making the order and receiving it. Gunasekaran, et al. (2001, 73) use the synonym “order lead time” to the time that takes between receiving the customer order and delivering the final product to the customer. In summary, the lead time is the time period that the entire order takes, from receiving the order request up to delivering the finished product to the end user.

Just in time (JIT)

The concept of just in time (JIT) comes from Japan (Toyota Production Systems) and it is in tight connection to the lean philosophy. In every step of the business processes, JIT aims to supply right materials at the right time and in the right quantity. (Tommelein & Li, 1999, 98) According to Vokurka and Lummus (2000, 91) JIT involves: quality control, lead time reduction, improvement of vendor performance, continuous improvement, waste reduction and proactive maintenance. In addition, Cao et al. (2007, 1222) mention that the just in time concept aims to maximal process perfection and eliminates waste. In conclusion, the JIT is a one feature of the lean concept and it is a processing method that strives to optimize the production so that the entire supply chain process would be as smooth as possible.

Process Mapping

The term process mapping refers to model development that points out the different relationships among the actors like people, activities, data and objects involved in the production process (Biazzo, 2002, 42). In addition, Hunt (1996, 2) mentions that the process mapping is a great tool for helping to re-design and improve the current and new business processes by helping to understand the processes and improve those if necessary.

1.6 Conceptual framework

In this part, the conceptual framework is presented and discussed in more detail. In the figure 3 below, the conceptual framework of the research is presented. As shown in the figure, the main concept of the study is supply chain management. Below this, there is supply chain performance as a second main concept. Following this, the study leads us to the supply chain performance evaluation and finally to the lead time management.

As the main objective of the study is to search ways to improve the global supply chain performance by squeezing the supply chain lead times, the concept of lead time management is divided to the lean supply chain, lean six sigma and value stream mapping themes. The rounded shape of the figure 3 visualizes the global context of the research. From these above-mentioned concepts, the theoretical foundation of the study is formed. The theoretical background aims to support the empirical investigation and also a possible new research gap can be found for the study by combining these two parts.

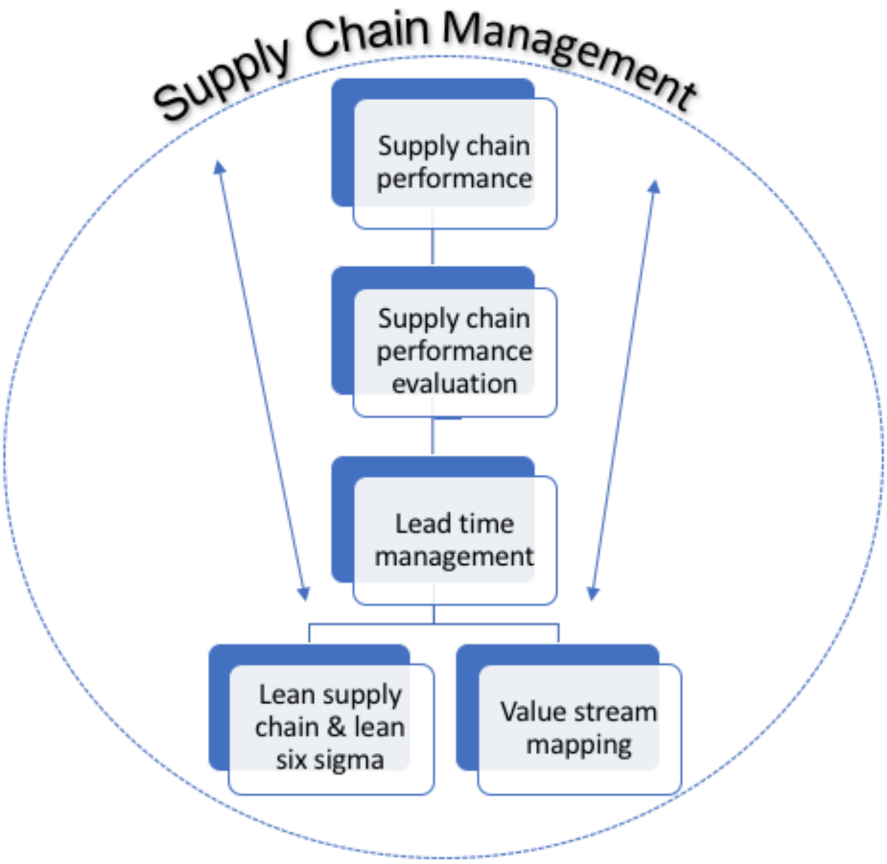


Figure 3. Conceptual framework

1.7 Literature review

In this section, we are going to go through the most relevant existing studies related to the topic of the work. The literature review aims to summarize the most essential academic studies about the content of the thesis and help to form a research gap for the current and future studies.

Although, the need for supply chain performance measurement systems keeps increasing, only few measurement systems are still available. Today, many supply chain systems are even larger and more complex, which makes it quite challenging for companies to measure its performance effectively. (Beamon, 1999) According to Gunasekaran et al. (2004) to create a desirable supply chain performance measurement system, all participants in the supply chain should take part in the development of supply chain-wide performance measurement system. Thus, in order to create a well-functioning measurement system for the supply chain processes, the whole supply chain network should be part of the development project and ideas should be created by win-win mentality for the common good.

Reflecting to the supply chain performance measurement systems, it is critical for supply chain management success and operational performance to monitor and measure how well the planning and execution are synchronized together (Bongsug, 2009). Two well distinguished performance indicators are the performance reliability and cost management. The cost management includes both in and outbound activities in supply chain, e.g. warehousing, inventory-holding costs and increasing asset turnover. Reliability indicators cover supply chain processes such as order fulfilment rate, safety stocks, inventory turns, inventory corruption and product claims. (Lee, et al. 2007, 446) Alternative performance indicators can be also formed and used because of the uniqueness and complexity of the different supply chain systems.

In recent years, the lean approach has gained significant interest in different business procedures. Originally introduced by the Toyota Production Systems, the lean method aims to reduce the waste and constantly do more with less resources. (Agarwal et al. 2006) Furthermore, as the global turbulent and fast changing markets are becoming norm, successful companies are introducing the "agility" in to the supply chain context, which entails more flexible and faster response to the market changes and customer preferences (Christopher, 2000). However, Christopher and Towill (2001) mention, that in some conditions and operational environments the hybrid strategy, which entail both agile and lean practices can be the best possible solution for the rapid changing business environment.

Arbulu, et al. (2003) conducted a case study regarding the delivery of pipe supports used in US power plants. The research was carried out by using the value stream mapping as a lean tool for analysing the current state of supply chain actions and developing a future state map for illustrating possible process improvement tactics for the supply chain. The data utilized in the study indicate that more than 96% of the time in supply chain actions is non-value-added time, which highlights the significant need for order-to-delivery lead time reduction. Furthermore, authors mention that in order to reduce the supply chain lead times the supply chain participants should consider the following: Early involvement of suppliers into the processes and design, use standardized communication methods and restrict the product design alternatives to limited set possibilities and finally use integrated computer systems to streamline design processes and product specifications.

Another interesting research conducted by Ward and Zhou (2006) investigated the relationship between lean/just-in-time practices and information technology integration on lead time performance. The empirical data (collected from 769 manufacturing companies) of the study indicate that the lead time reduction achieved through the information technology integration investment depends mostly on the implementation and the use of lean/just-in-time practices. Consequently, the lean/just-in-time practices can reveal the full potential of both inter-firm IT integration and between-firm IT integration, and the main improvements of the lead time reduction can be achieved by combining the IT and lean/just-in-time practice within and between different companies in the supply chain.

Treville et al. (2004) examined in their study, whether the demand chain performance can be improved by focusing on the lead time reduction or concentrating on improving the transfer of demand information upstream in the supply chain. The study used a Nordic pulp and paper producer as a case example. According to the research, the authors mention that manager in various companies believe that supply chain lead time reduction is expensive and difficult, and that information systems are the easiest remedy for lead time reduction. Based on the findings, the authors propose the following ideas: (a) Improvements for the supply chain performance should be made by carefully analysing the demand (b) For supply chain that face demand variability the market analysis and demand transfer is necessary (c) Trust and relationship durations are essential aspects in the demand information transfer but it can be challenging. (d) Companies with short supply chain lead time should concentrate to the demand information change with different actors and companies with long supply chain lead time should concentrate their effort on integrating their planning and forecasting systems with their customers. (e) Finally, the aim should be improving the supply lead times over demand information transfer.

Furthermore, Wee and Wu (2009) used a case study method to describe how the lean supply chain through value stream mapping can improve the quality of the product, lower costs and reduce the lead time. The research used the Ford Motor company in Taiwan as an example for the analysis. The paper reveals that value stream mapping (VSM) is a useful lean tool for eliminating and identifying waste in the supply chain processes, and that companies introducing lean practices should realise that lean is a long-term philosophy for successful companies like Toyota, and therefore the short-term benefits and savings should not be targeted.

By reflecting to the previous studies that has been made about the topic, one can safely say that the topic has been quite broadly researched by different authors and practitioners. But, due to the complexity and uniqueness of different supply chains, true research gaps can be found and studied from the field in question. Thus, case studies can bring interesting aspects to the research field, because of the specific features these different industries, companies, products and perspectives are providing to the existing literature and research.

2 SUPPLY CHAIN IMPROVEMENT

In this second main chapter of the thesis, we are going to discuss about the theoretical background of the study. The theoretical foundation will give a solid base for both empirical research and conceptual framework of the study.

Management and improvement of supply chain operations have both strategic and tactical/operational characteristics behind its back. The strategic side refers to the long-term decisions to run the supply chain activities, whereas the operational and tactical features are related to the daily decisions and actions to manage the supply chain operations. Therefore, it is about how companies align the daily actions to the long-term strategic vision. And those firms that can do this with the most efficient way, gain competitive advantage against other rivals on the market. The following list, will provide some of the most important principles of managing and improving supply chain activities: (Ritvanen, 2011, 136)

- Simplifying processes
- Lead time reduction
- Real time communication and information sharing
- Common planning
- Reducing waste and errors
- System integration between supply chain parties
- Customer orientation
- Transparency
- Reliability
- Flexibility

All of these, above mentioned principles are associated to various different business processes in the supply chain operations. Simplifying processes, reducing lead times and improving the customer orientation for example, are all linked to process improvements that ultimately strive to reduce costs and improve the customer satisfaction. Furthermore, Mason-Jones et al. (2000) claim that: “Supply chain performance improvement initiatives strive to match supply and demand, thereby driving down costs simultaneously with improving customer satisfaction.” This is the main objective of supply chain management, in short supply products and services with the minimum costs, maximum value and in the lowest possible time.

This value driven concept is linked to a well distinguished model provide first by Michael Porter called “value chain” (illustrated in the figure 4 below). In the model, the emphasis is to search ways to provide maximum value in the eyes of the customers. These value chain activities have two types of activities, primary activities (inbound logistics, operations, outbound logistics, marketing and sales, and services) and secondary activities (infrastructure, human resource management, technology development and procurement). These integrated activities provide the base for the competitive advantage and those organizations that can deliver value for the customer with the most efficient way have the greatest potential for success. (Christopher, 2005)

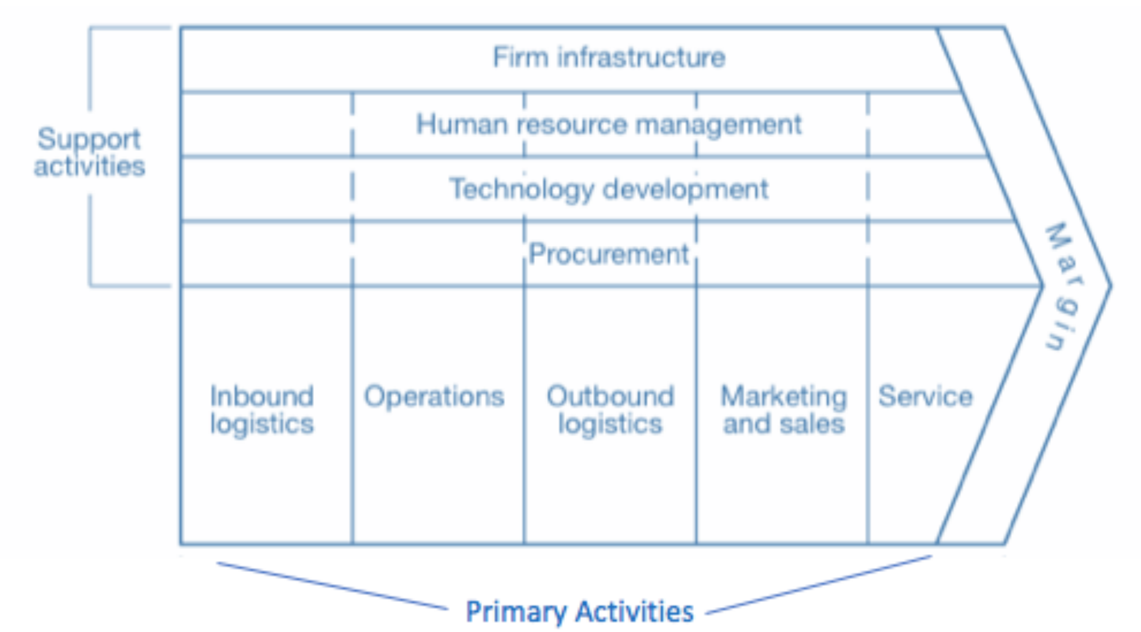


Figure 4. Value chain model (Adapted from Christopher, 2011, 10)

These value chains that constitute of several different firms in the global context, are the new source of competitive advantage. Additionally, companies that align the upstream and downstream flows with suppliers and customers are seen as one of the most successful firms in the modern-day markets (Frohlich & Westbrook, 2001). Thus, it is important to search new and better ways to manage the complex supply chain activities. In addition, like Heikkilä (2002) mentions, the supply chain improvement should star from the customer side, meaning that by understanding customer needs and having efficient demand chain structure, meaningful business benefits can be achieved. He also claims that the traditional supply chain management concept should be transformed to demand chain management. This just indicates that the customer role has increased in the recent years and firms that react to those changes in the demand side, can have significant positive gains from it.

Although, supply chain operations consist multidimensional aspects (e.g. sourcing, manufacturing, distribution etc.), this following study concentrates on the supply chain lead time reduction and time management as the core theme. Thus, other supply chain related issues and improvement areas are not discussed any further in this study.

2.1 Supply chain delivery performance

One key attribute in today's successful business is to serve customers with reliable on-time deliveries (Guiffrida & Nagi, 2006). This delivery performance indicator can be considered as one of the most important metrics in supply chain context, because it contains information all the way from first-tier suppliers to the customer end. These timely deliveries have positive impact on various business indicators, like for example better competitive advantage against competitors and increased customer satisfaction level by the company stakeholders. (Gunaselaran, et al. 2001; Nakandala, et al. 2013) Delivery performance can be defined as a metric of how well the company supplying products and services can meet up the end customer expectations. (Rao, et al. 2011) Hence, when the delivery reliability is high and consistent, firms can expect higher customer satisfaction levels and increased profitability.

Delivery windows are often used in the performance measurement systems where limits or due dates are being measured in the integrated production-distribution systems. This delivery window can be defined as a time period within the delivery can be received. (Bushuev, 2018) For instance, if the delivery is agreed to be delivered for the customer in between 1.-3. of March, that is the delivery window for the delivery. Thus, anything coming before or after those agreed days, can be seen as inefficiency which can create extra costs to the supply chain and lower the customer satisfaction level. According to Bushuev and Guiffrida (2012) in the supply chain context, these early or late deliveries can be considered as a form of waste; early deliveries can produce excess inventory holding costs, while late deliveries can have impact to the lost sales, production stoppage expenses and loss of goodwill.

While operating with these, often complicated supply chain systems, problems in the delivery chain tend to have the snowball effect in the system. Meaning, that company managers typically increase buffering, additional stock levels, overcapacity or postpone confirmed delivery schedules if problems emerge, which ultimately increase costs and lower the customer satisfaction. (Vachon & Klassen, 2002) Furthermore, Rao et al. (2011) mention, that poor supply chain performance is a result of increased number of resources, operations and organizations in supply chain activities, which damages the synchronization among the individual processes. Thus, companies have to control these individual processes and actors in the supply chain in order to maximize the supply chain delivery performance.

Like any business process, there can be some issues to handle these on-time deliveries. Forslund and Jonsson (2010) found that major obstacles for the on-time deliveries are manual data collection, registration and reporting generation. Moreover, the study conducted by Vachon and Klassen (2002) indicate that process/product complexity (structural factors) and management system uncertainty (infrastructural elements) were substantially associated to delivery performance (speed and reliability factors). The authors also mention that a great emphasis should be directed to the information exchange development, building better supplier capabilities and by improving technological and organizational systems.

Various metrics has been used to determine the delivery performance. Stewart (1995) names three measures for delivery performance;

(1) delivery-to-request date,
(2) delivery-to-commit date, and
(3) order fulfilment lead time.

Milgate (2001) on the other hand, uses four variables (two of speed and two reliability variables) to measure delivery performance. The speed variables are delivery lead time and throughput time, and the reliability metrics are the percentage of late deliveries and average lateness for the late deliveries. Furthermore, Guiffrida and Nagi (2006) state, that delivery performance indicators should include both financial and non-financial metrics. These can include for example, measurements of customer satisfaction and transportations/logistics costs. In addition, Rao et al. (2011) states that there can be used several sub-measures that are connected to the delivery performance, and companies have to decide which of these sub-measures are most useful to determine and evaluate the supply chain performance. These sub-measures include e.g. on-time delivery, delivery reliability, delivery service, faster delivery times, delivery frequencies, delivery synchronization, delivery speed, order fulfilment lead time, supplier’s delivery performance etc. So, many different measures can be used to assess the supply chain delivery performance and companies has to identify and pick up the right measures that are appropriate for the situation and company purposes.

According to Bhagwat and Sharma (2007) by carefully selecting a suitable delivery channels, improving scheduling practices and optimizing the location polices firms can increase the delivery performance. Another feature that has been found to help companies to improve the delivery performance is the use of electronical data interchange (EDI). This helps companies to link up the customers and suppliers through the EDI interface, which can improve timely deliveries and information exchange between different links in the supply chain. (Ahmad & Schroeder, 2001) By taking advantage of the current technological tools and software, firms can discover new and improved ways to increase their operational and strategic performance. Furthermore, while more speed, reliability and flexibility are being expected from the supply chains, management should pay more attention to utilize and manage these complex business networks.

2.2 Supply chain performance measurement and evaluation

Today, companies are expected to measure and evaluate almost everything, regardless of the context or business function. Firms have to measure for example, how happy their customers are to the customer service, how many days the batch delivery will take and how many sick days there is on average (per week) in the factory etc.

According to Neely et al. (1995, 80) the performance measurement can be defined as having different metrics to quantify the efficiency and/or effectiveness of an action. Nabhani and Shokri (2009) on the other hand, define performance measurement as a process of gathering data, exchanging information, analysing and measuring the data to develop the key performance indicators for the company. Additionally, Chae (2009) mention that KPI’s or performance metrics offer a general overview of the supply chain, which helps to assess the actual performance against the forecasted, and these potential gaps between these two (forecasted vs. actual) give the opportunities for the improvements. Furthermore, Bhagwat and Sharma (2007) say that measuring the performance is a crucial element of high-performing planning, control and decision-making systems in the companies. Thus, the importance of measuring the business performance cannot be overemphasized. For the purposes of measuring the business performance, Gunasekaran and Kobu (2007) adduce the following:

- Identifying success.
- Identifying if the customer needs are met.
- Helps companies to identify its processes.
- Identify problems, waste and improvement areas.
- Providing fact-based decisions.
- Tracking the improvements.

According to the previous literature, four main performance indicators to assess the supply chain performance has been universally identified. These metrics are flexibility (Angerhofer & Angelides, 2006; Beamon, 1999), quality (Beamon, 1999; Shepherd & Günter, 2006), cost (Gunasekaran, et al. 2004) and time (Shepherd & Günter, 2006; Beamon, 1999). Furthermore, these supply chain performance measurement indicators have been divided to quantitative and qualitative metrics, cost and non-cost, and also strategic/tactical/operational metrics. (Gunasekaran, et al. 2004; Shepherd & Günter, 2006; Chan, 2003) Beamon (1999) on the other hand, uses a triangular framework to model the three main aspects of the supply chain performance measurement systems. These three indicators are the output measures (generally customer responsiveness), flexibility measures (how fast the system reacts to uncertainty) and resource measures (generally costs). The goals and purposes of these measurement types are illustrated in the table 1 below.

Performance measure type	Goal	Purpose
Resources	High level of efficiency	Efficient resource management is critical to profitability
Output	High level of customer service	Without acceptable output, customers will turn to other supply chains
Flexibility	Ability to respond to a changing environment	In an uncertain environment, supply chains must be able to respond to change

Table 1. Supply chain performance measurement goals and purposes (Beamon, 1999)

In addition, the table 2 underneath, shows a list of performance measures for the three above mentioned main supply chain performance indicators (resources, output and flexibility). Flexibility is the newest addition for the more generally accepted and used resource and output indicators. (Beamon, 1999) All of these performance indicators are linked to the overall performance of the supply chain processes. So, the better companies handle these indicators, especially those important to the company preferences, the more competent firms can be in operational field.

Resources	Output	Flexibility
1) Total cost 2) Distribution costs 3) Manufacturing costs 4) Inventory 5) Return on investment (ROI)	1) Sales 2) Profit 3) Fill rate 4) On-time deliveries 5) Backorders/Stockout 6) Customer response time 7) Manufacturing lead time 8) Shipping errors 9) Customer complaints	1) Volume flexibility 2) Delivery flexibility 3) Mix flexibility 4) New product flexibility

Table 2. List of performance measures (Adapted from Beamon, 1999)

Furthermore, Beamon (1999) mention that: “Individual performance measures used in supply chain analysis have been shown to be non-inclusive.” Meaning that, by using only one performance measurement indicator to evaluate the supply chain performance is not sufficient enough, to have the best possible picture of the system performance. Thus, various different indicators should be used together, to have the best possible estimation of the supply chain performance. In addition, due to the complexity of the supply chain systems, a single measurement indicator (for example flexibility) won’t give a comprehensive assessment of the system and its total performance and many different indicators should be used together.

Due to the system complexity and generally large size, choosing appropriate supply chain performance measurement system can be difficult for many companies. In addition, managers are facing challenging task to determine the relevant key performance indicators (KPI’s) based on the business goals and then how to measure and implement them (Gunasekaran & Kobu, 2007). Chan (2003) also mention, that usually qualitative measures (quality, flexibility, visibility, trust and innovativeness) are lacking behind to the quantitative measures (cost and resources), because these qualitative indicators are conceptual ideas and people tend to judge these by their own understanding. In other words, people understand numbers over soft criteria and decisions are made based on numbers over qualitative values. Furthermore, Beamon (1999) state that traditionally these performance measures has been connected merely to cost and customer responsiveness metrics. These cost indicators are for example different operational costs and inventory costs, and the customer responsiveness measures on the other hand have been connected to stock-out probability, inventory fill rates and lead time measures.

Gunasekaran et al. (2001) provided a clear model (figure 5. below), to illustrate how the different measures and metrics are connected in the supply chain model. These different steps in the supply chain are the following: Plan, source, make/assemble and deliver. Furthermore, these different steps can incorporate various indicators to be measured, depending on the need and resources available in the company. Ultimately these connected steps are all influencing to the customer satisfaction and service level.

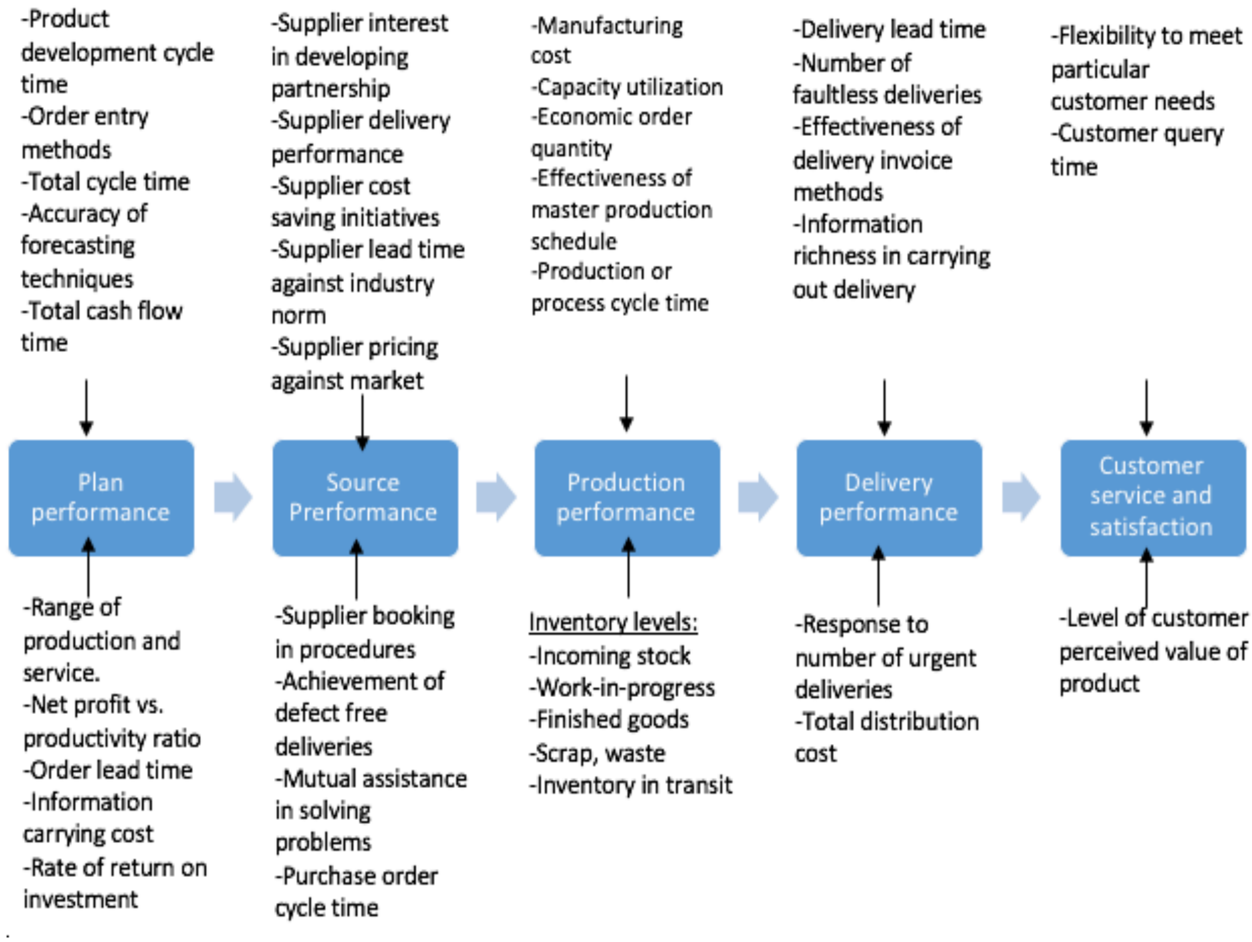


Figure 5. Measures and metrics in the supply chain context. (Adapted from Gunasekaran et al. 2001, 85)

Nowadays, most of the information systems such as SAP, Oracle EPM and i2 are using this complex information to measure and monitor company critical information to optimize and improve the supply chain performance (Cai, et al. 2009). Although, these different ERP-systems (Enterprise Resource Planning) and company data-bases are providing more and more information for the company managers and employees, these people should also be able to analyse and find the business relevant information from the large amount of data and use it for the advantage, otherwise the data gathering is useless, and the performance measurement cannot be done precisely.

As mentioned earlier in the chapter, number of reasons and implications for measuring and evaluating the supply chain performance has been identified. Furthermore, Lambert and Pohlen (2001) conclude that most of these supply chain metrics are focusing only to single firm targets and objectives and are not seeing the entire supply chain as a driver for value or profitability increase. This is why companies have to proactively search new ways to improve the supply chain performance with all the different members in the supply chain. This win-win mentality helps firms to maximize the profitability, not only for the company itself, but also for the entire value chain. Moreover, firms should use both financial and non-financial metrics to evaluate and measure the system performance. This will enable companies to have the most versatile information of the supply chain operations and customer preferences. Finally, like Shepherd and Günter (2006) conclude, firms should handle these measurement systems in a dynamic way that must respond to the environmental and strategic changes. This way companies can cope with the constantly changing environment and find new innovations and indicators to manage these complex business networks.

2.3 Lead time management

As discussed in the introduction part, the lead time can be defined as a time period that the entire order takes, from receiving the order request to delivering the final product to the end customer. This typical order cycle is presented in the figure 6 below, where the basic components of the order process are shown. Additionally, different business processes can have their own lead/cycle times to be measured (e.g. manufacturing lead time or delivery lead time), but in this chapter we are focusing on the supply chain lead time, because of the research topic.

Customer places order	Order entry	Order processing	Order assembly	Transport	Order received

Figure 6. The order cycle (Christopher, 2005, 150)

In today's global just-in-time environment, shortened and consistent lead times are seen as major source of competitive advantage (Christopher, 2005). In addition, Hammami and Frein (2013) mention, that in order to success and survive in the competitive markets, companies have to both shorten the delivery lead times and make them work faster with the minimum costs to gain competitive advantage. Stalk (1988) also emphasise, that the way world-class companies are managing time, for example in production, new product development and introduction, sales, distribution show the most powerful new source of competitive advantage.

Time-based competition (TBC) is a term for the recognition of the strategic importance of time in the field of supply chain activities and other business functions (Thomas, 2008). TBC is an approach where organizations identify time as a powerful source of competitive advantage and it has been used by many successful companies in Japan (Stalk, 1988). Droge et al. (2004) propose two approaches to become time-based competitor. The first approach relates to the individual company and the search for internal opportunities to reduce lead time. There can be several ways to improve these internal processes and reduce cycle time, for example process waste elimination can be one of those tactics to improve internal performance. The second approach to become a time-based competitor is more like a collective method. This approach emphasizes the usage of other members in the supply chain to increase the flow of information and reduce lead times throughout the supply chain. (Thomas, 2008; Droge et al. 2004) Thus, time management can be seen as a binomial approach, where both internal processes and external resources should be controlled in order to gain the maximum results in the time-based competition.

Furthermore, as the supply chain processes are made in less time, all the participants in the supply chain are able to operate more efficiently, which leads to the lower inventory levels throughout the system, which ultimately lowers the overall operational costs. Improved cycle times are also associated to the faster transfer of capital throughout the system, which increase the cash flow and financial performance of the entire supply chain. (Brewer & Speh, 2000) Furthermore, Giri and Roy (2016) also claim, that lead time reduction can lower safety stock levels, reduce stock-out loss and also enhance the customer service level. Branch (2009) also cover that the supply chain cycle time reduction can improve three primarily objectives in business; improved competitiveness of the product, decrease days of inventory held and lower the cash conversion cycle. Thus, lead time reduction and reliability are undeniably key aspects, that organizations in every industry have to pay more and more attention in order to success in the global competition. The table 3 below, draws together some of the well distinct benefits of lead time reductions.

Benefits of reducing supply chain lead times
1) Improved customer satisfaction
2) Lower costs
3) Better flow of capital
4) Lower inventory levels
5) Higher market share

Table 3. Summary of lead time benefits

Although lead time reduction is now seen as a major aspect of the supply chain systems, some challenges are also present to challenge the system improvements. Hammami and Frein (2013) claim that many of today's supply chains are complex business networks, which consist several layers of geographically dispersed actors, and these worldwide networks create extra pressure to the lead time management (if there are no additional stocks) and consequently, make the lead time control a challenging task. Additionally, Heydari (2014) also mention, that long, variable and stochastic lead times can cause problems to the supply chain service levels, because of the increased stock-outs and lower product availability. Furthermore, McLean (2017) state, that the geographical distance is usually not the main issue, when dealing with long lead times, and he covers the following factors driving the long lead times:

- Delays in processing the orders (in both the supplier's and buyer's end).
- Delays associated with arranging payments.
- Suppliers lead time is added to the buyer lead time.
- Suppliers are batching up orders to run them together in a large run.

- Delays in arranging shipping.
- Consolidation delays.
- Delays at cross-docks and ports.
- Capacity issues at the supplier side.
- Bad communication and errors.

There can be several other reasons why lead times are not matching the target dates, and why companies are not able to manage these complex supply chain networks to increase the business performance and improve the customer satisfaction. Christopher (2011) calls this a lead-time gap, which refers to the problem that most organizations face; the entire order process, from procurement to delivery takes longer than the time customer is prepared to wait for it. Figure 7 illustrates this problem. The key in the supply chain lead time improvement is to reduce the lead-time gap as much as possible with the minimum costs. And as more and more today's global customers are expecting shorter delivery times, companies have to constantly search new ways to reduce the lead-time gap and keep the customer satisfaction highest level possible.

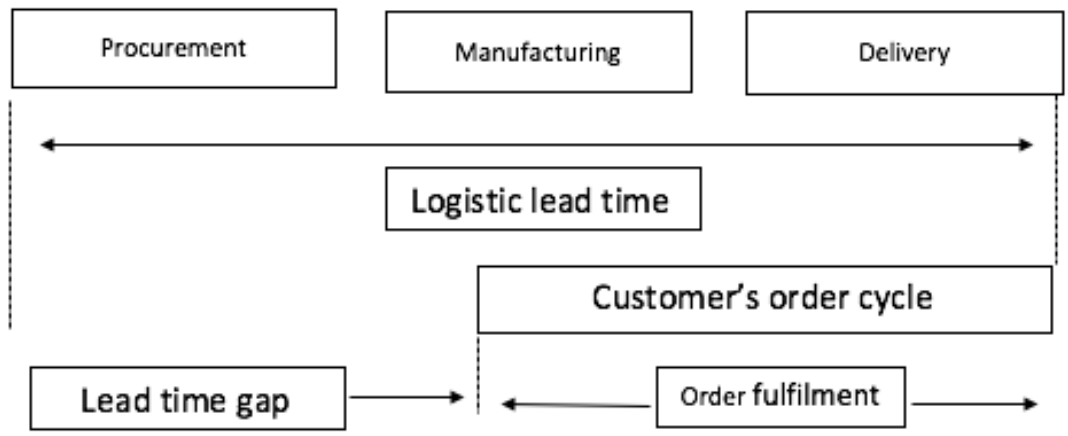


Figure 7. Illustration of the lead time gap (Adapted from Christopher, 2011, 84)

On the other hand, in the figure 8 below, the basic components of lead time are presented. The figure aims to demonstrate, what kind of different supply chain processes there are that can have influence on the total lead time. Hence, the total lead time is a cumulative indicator, including several different business processes that add up to the total cycle time. Again, this is just an example of what kind of components there can be to impact the total lead time, and naturally for example service companies have completely different components that affect to the total lead time than manufacturing companies. These different supply chain links are the ultimate source of total lead time. Thus, the most successful firms are those who can manage these links and create mutual benefit for customers and for the actors in the supply chain network.

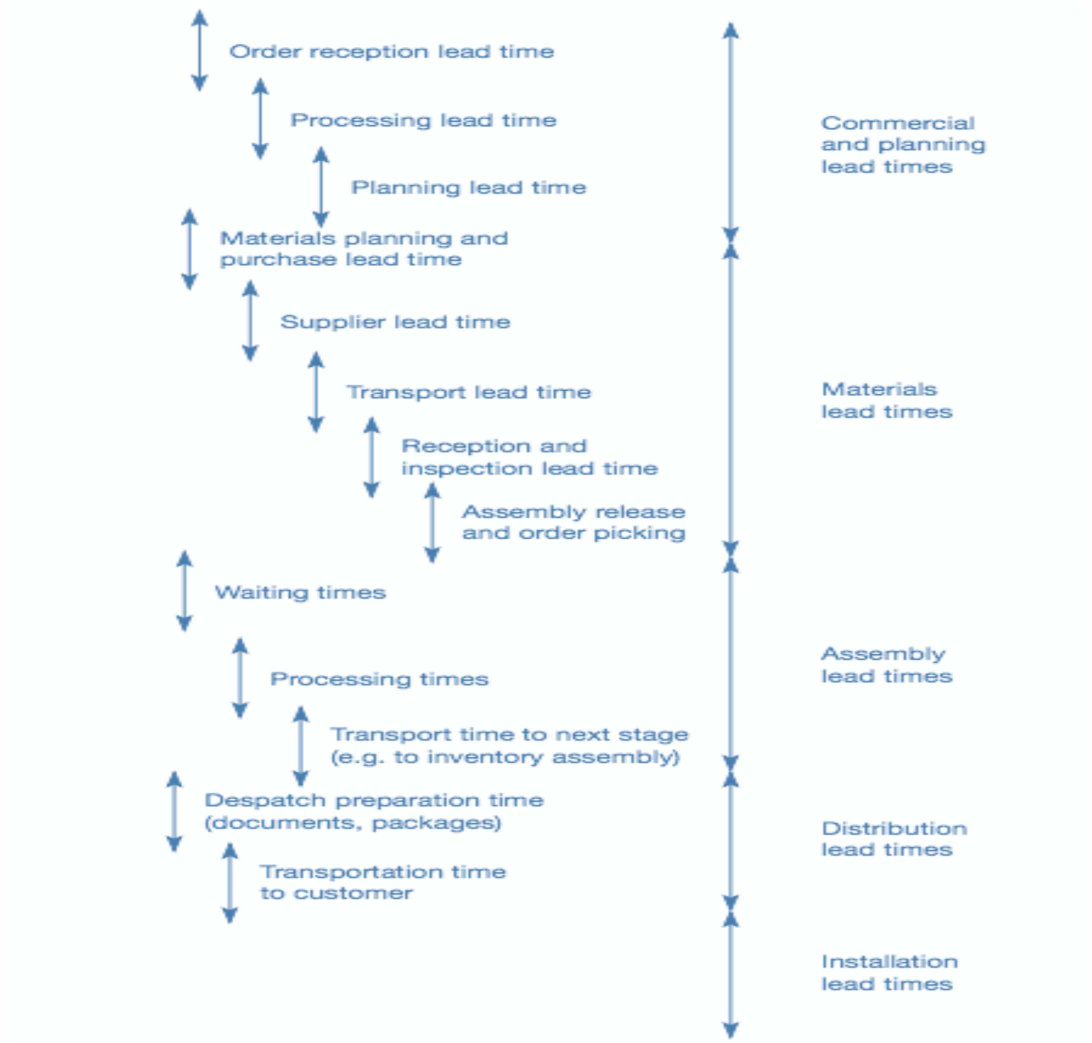


Figure 8. Basic components of lead time (Adapted from Christopher, 2011, 127)

A comprehensive lead-time reduction strategy starts by identifying the most distinct bottlenecks in the system and removing those. The first step is to examine the entire supply chain as a series of successive transactions. After that, the second step is to spot and attack lead time bottlenecks, beginning with the largest ones and moving on to other constraints in other supply chain functions. Third step is to monitor the system performance and constantly searching ways for improvements. (Tersine & Hummingbird, 1995) According to McLean (2017) for companies that are trying to achieve reductions in lead times, first the lean thinking should be applied to the organization, and by using the value stream map to identify and understand drivers behind these lead times, process improvements can be made. Furthermore, Christopher (2005) mention that one effective way of reducing the order cycle time is to have improved visibility of the demand in the supply chain, by having earlier notice of their requirements. If the first-tier suppliers can see right to the end of the pipe line, the entire logistics system can become much more responsive to the actual demand. This responsiveness and early information adaptation can both improve the customer service level and lower overall costs. (Christopher, 2005) Thus, it is important to cooperate with the members of supply chain and utilize comprehensive information on the end customer needs. This information exchange can be accomplished by using advanced technology (e.g. ERP-systems) to communicate information from the customer end to the supplier side.

Ward and Zhou (2006) on the other hand mention that, in the manufacturing industry, two general approaches have been used to reduce lead times; information technology (IT) integration both within and between companies in the supply chain and process improvements that are usually referred to lean/just-in-time practices. Real time information exchange between different firms in the supply chain helps companies to track and react changes in the supply chain, which can lower the overall operational costs and raise the customer satisfaction due to the better forecasts and improved supply chain reliability. Furthermore, Simatupang and Sridharan (2005) say, that the integrated data exchange helps firms to fulfil demand more quickly and shorten the order lead times with the relevant, timely and accurate information. The RFID (radio frequency identification) technology can be one contemporary solution for various firms to improve the supply chain performance. The RFID technology is an automatic data identification (auto-ID) system, which gather data and identifies items without human intervention or data entry process (Wyld, 2006). This technology allows companies to improve lead times, reduce inventory levels, enhance collaboration with other supply chain member and increase the information and material visibility in the supply chain. (Attaran, 2011)

Lean and just-in-time on the other hand are more like philosophical and operational methods to boost the supply chain performance. This performance increase can be achieved through for example, improved product quality, less inventory and better responsiveness to customer demand. In addition, according to study by Christensen et al. (2007), the emphasis should be directed to lead time variance control over the traditional lead time average control, since the study indicate that the lead time variance leads directly to the financial performance, whereas supply chain lead time average does not. Thus, mitigating the lead time variance can improve the supply chain performance, profitability and competitive advantage over competitors.

In other words, time is more valuable than ever before. Constant market pressure, shorten product life cycle and changing demand are creating pressure to become more flexible and quicker in the global markets. Like mentioned before, lead time reduction in the supply chain context, can for example increase the customer satisfaction, reduce costs and improve the market share. Besides, as more supply chains are fragmented (e.g. product components are sourced from abroad), firms need to broaden the strategic vision cross the borders and approach the process improvements collectively with other supply chain members. These value chains are the new source of competitive advantage, and those who can exploit them with the maximal customer value are the leading firms in the global economy.

2.4 Lean supply chain

The traditional lean concept originates from Toyota Production Systems (TPS) and was first introduced in the late 1940s in Japan, aiming for continuous improvement and respect for people (Myerson, 2012). The lean operational system was used to eliminate waste and excess from the Toyota production flows and represent a new alternative model to widely used mass production method (Hines, et al. 2004). In addition, the waste (muda in Japan) in all forms, should be removed by rationalizing the production processes. The lean system focuses to the inter quality aspects, like for example, less production delays, zero defects as well as improved quality towards the customers, which can lead to higher efficiency, productivity, customer value and also to major cost reductions. (Machado & Leiter, 2010) Furthermore, according to Pepper and Spedding (2010) seven forms of waste have been generally identified:

1. over-production
2. defects
3. unnecessary inventory
4. inappropriate processing
5. excessive transportation
6. waiting; and
7. unnecessary motion.

In addition, to understand what the “waste” can be in the business processes, the differences between value-adding and non-value adding activities (or waste and non-waste activities) gives a good idea of that. The following table 4 below presents the differences between these two forms of activities. The value-adding activities are those that add value for the customers and non-value adding activities (or waste) are those that does not add any value for the customers.

- Value-added activities
- ✓ Activity the transforms material or information and that the customer is willing to pay for
- Non-value-added necessary activities
- ✓ Activities that add no value but are required or necessary based upon regulatory, state of technology, etc. requirements
- Non-value-added activities
- ✓ Activities that create no value in the eyes of the customer

Table 4. Value-added vs. Non-value-added activities (Myerson, 2012, 17)

Today, when the “lean” concept has become widespread and the concept has now spread into different organizations and business functions, like for example defence departments, construction companies, hospitals and even financial institutions are using the lean method. (Liker & Morgan, 2006) This entails also a fundamental shift from traditional manufacturing processes to lean supply chain and logistics processes, that has been now transformed to lean procedures (Myerson, 2012, 15). Therefore, lean is not a pure manufacturing guideline anymore, which can only be used in companies producing mass products for the end customers, but it can be used for example in service business and customized production for limited customer segments as well. As the lean methods can be used virtually anywhere in these days, Hines and Taylor (2000) provide a general framework of five principles of how to transform a company to “lean”, which can be seen in the figure 9 below.

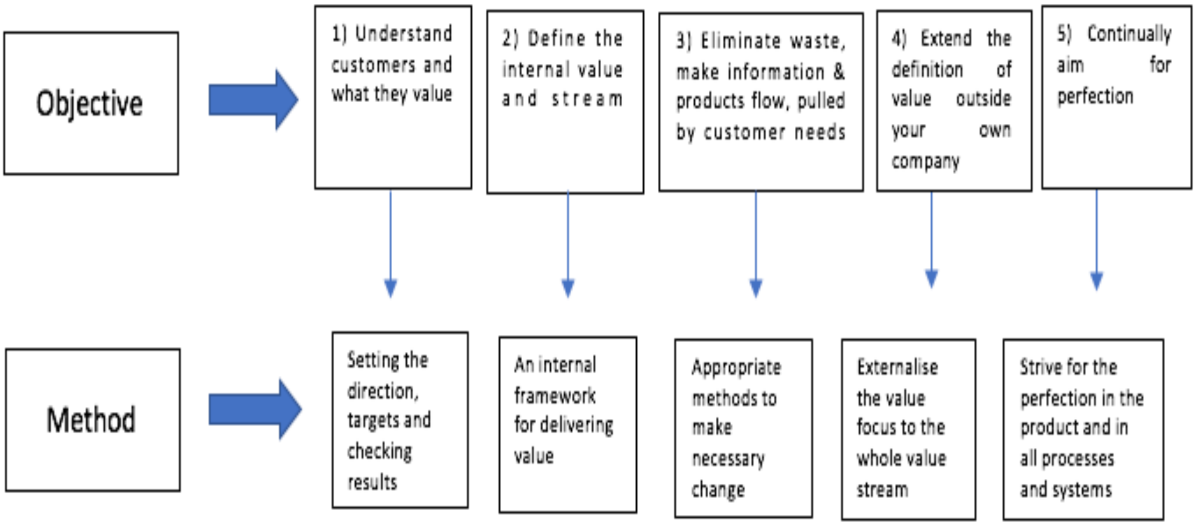


Figure 9. Five principles of going lean (Hines & Taylor, 2000)

First, the main objective is to understand the customer needs and what they value most. This target can be reached by setting directions, targets and constantly checking how results have been achieved. The second objective is to define the internal value streams. This means that the company should identify what are the value streams for the product or services they are providing for the customers, that is recognise the internal processes that add value for the customers. The third principle is to eliminate all the waste and provide products only what is pulled by the end customers. After this, the fourth principle is to extend the value stream focus outside company boundaries to the whole supply chain view. Finally, the fifth objective is to constantly aim for perfection by improving all the processes and systems in the value chain. (Hines & Taylor, 2000) These five principles, are just the basic steps or guidelines of how companies can adapt to the lean systems.

In supply chain context, the term “lean” refers to the total integration of entire flow of raw materials to end customers (Lamming, 1996). Lehtinen and Torkko (2005) mention that, the lean supply chain aims to wider development of supplier improvement in the network level and that the way of working is now changed to more proactive way of working through the entire supply chain. Within these lean supply chains, the way of working with different actors in the supply chain has changed to more collaborative way of working to share common goals, creating value to customers and reduce total costs along the supply chain. In addition, Arif-Uz-Zaman and Nazmul Ahsan (2014) mention that one efficient way of creating value is to mitigate waste from each tier of the supply chain by using the lean supply chain concept. Furthermore, Vonderembse et al. (2006) mention that the lean supply chain is a method to eliminate non-value adding steps along the supply chain and uses the continuous improvement system to improve the total supply chain network performance.

On the other hand, as the complexity keeps increasing in the global markets, the lean methods are becoming increasingly difficult to implement and maintain over time (Mollenkopf et al. 2010). In addition, Vonderembse et al. (2006) remark that these lean supply chains must be even quicker to respond to market changes, due to the changing customer requirements and shorter product life cycles that the customers are demanding. Additionally, Myerson (2012) mention, that some of the biggest barriers to lean implementations are low top management commitment, lack of interactions with the suppliers and other partners and the necessity for cultural change in the company. Thus, the lean cannot be seen as a pure toolkit for the companies that are trying to improve their business processes, but the company culture and employee attitudes has to be adjusted to these lean changes, in order to improve these processes in the long-run.

The following sub-chapters of lean supply chain are discussing some of the main principles and tools of lean philosophy and process improvements. These following topics are; Value Stream Mapping, PDCA cycle, kaizen & just-in-time and FMEA method. All of these themes can be used to improve different business processes and identify aspects that need further examination and deeper analysis.

2.4.1 Value Stream Mapping

The Value Stream Mapping (VSM) is a paper and pencil method that uses the mapped presentation to illustrate all the actions (both value adding and non-value adding) in the production process of a particular product to give a bigger picture of the entire process. The VSM method demonstrates how the flow of both materials and information move through the whole supply chain system from suppliers to the end customers giving information of how well the process is performing currently and what is the ideal or desirable future state of the supply chain process. (Batra, et al. 2016; Lian & Landeghem, 2007) The Value Stream method is highly associated to the lean philosophy, where activities that are not adding value to the end customers has to be eliminated as a “waste”, and that has to be made for the entire system, not just for a single department or function in the company (Arbulu, et al. 2003).

To successfully implement the Value Stream Mapping to the practice, the following primarily steps are needed (Abdulmalek & Rajgopal, 2007, 255):

- Choose a particular product or product family as a target
- Develop the current state map
- Create a future state map
- Make the necessary changes and improvements for the system

After the target product has been selected, next step is to draw the current state map by gathering various information from the shop floor level. The next step is to sketch the future state map by using the information from the current state drawing. The future state step is the most important part of the VSM process, as it shows the relevant information and desired targets for the improvements. The final step is to implement the plan in order to improve the supply chain processes in continuously manner. (Rother & Shook, 1999) A summary of the value chain analysis method is presented in the figure 10 below.

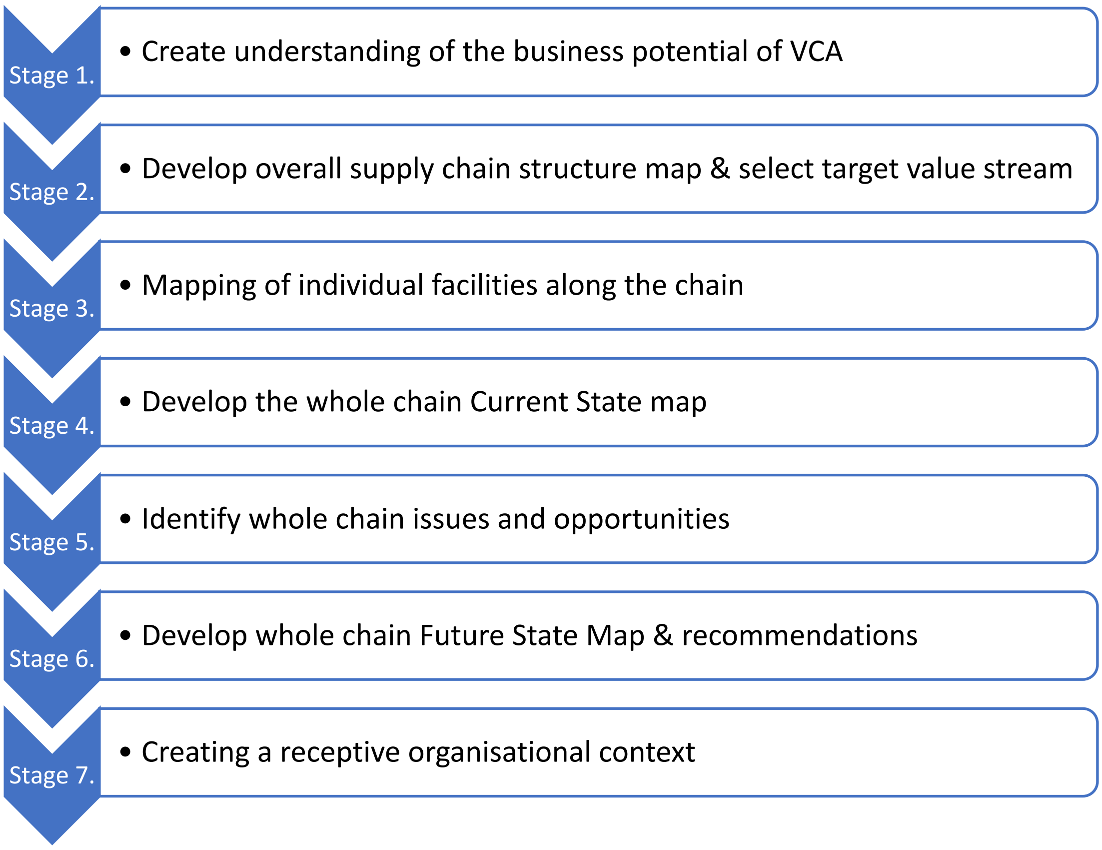


Figure 10. Summary of the value chain analysis process (Adapted from Taylor, 2005, 747)

According to Arbulu et al. (2003) by having both the current and future state maps, it provides the required vision and understanding for the future process improvements. This helps managers and business practitioners to gain better view of the supply chain processes and to identify the possible bottlenecks in the system, and eventually add remedy for these issues. Furthermore, Seth and Gupta (2005, 50) mention, that the importance of VSM is that it gives information regarding the total processing time, and total lead time of the processes and the improvements can be made based on these findings. Thus, the VSM is a useful method when analysing the total supply chain lead time and providing possible solutions to improve the process cycle times.

The figure 11 below, provided by the Hines and Taylor (2000) demonstrate the current state map (imaginary supply chain example) and the different value flows between various actors in the supply chain. Additionally, the figure shows the total production lead time (ranging from 26-110 hours) and the value adding time (average 9.75 hours) which indicates that most of the time in the delivery chain is not value-adding time (waste). This big picture (value stream map), helps managers and employees to identify possible bottlenecks and activities that are not adding value for the customers, and based on those spots and bottlenecks, process improvements can be made.

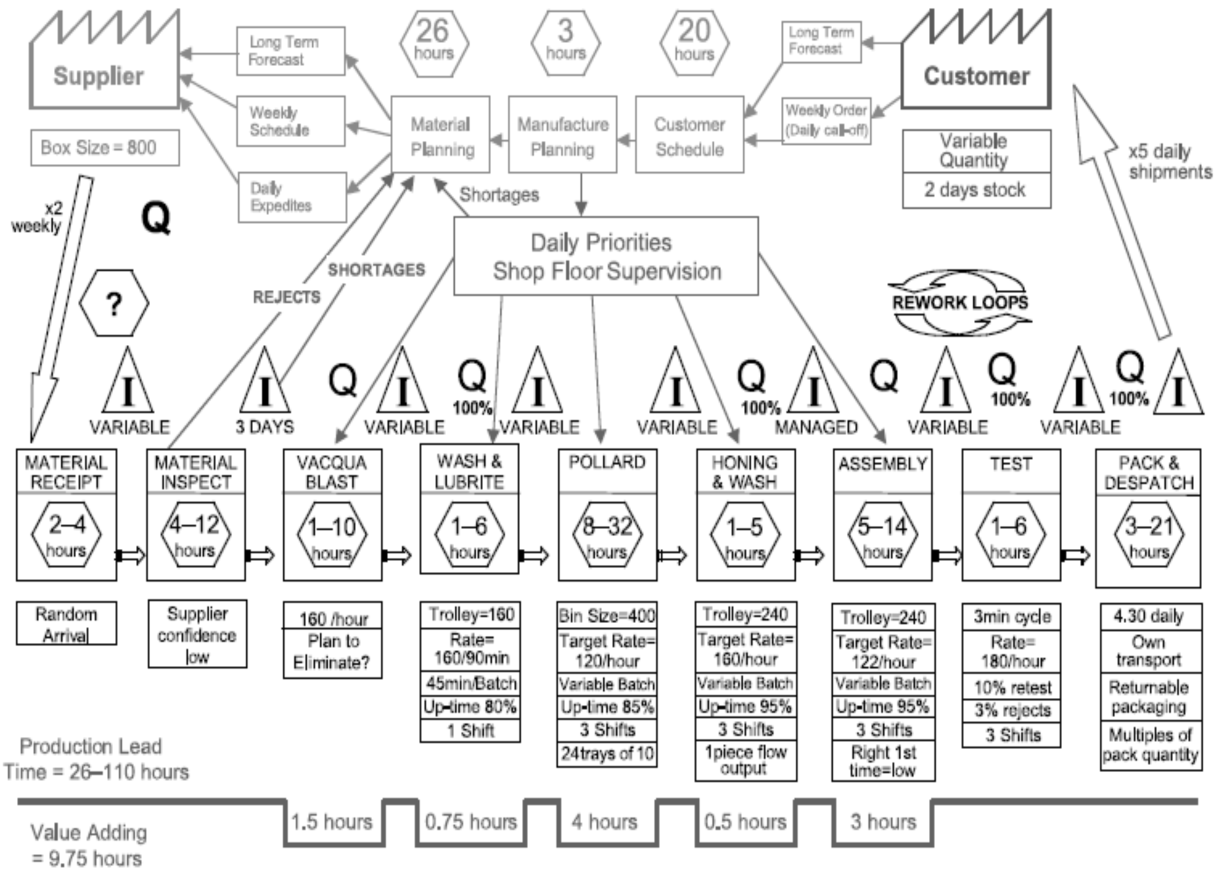


Figure 11. Value Stream Map (Adapted from Hines & Taylor, 2000)

There can be several benefits of using the VSM method. Myerson (2012, 118) suggest the following benefits of using VSM:

- Shows the connections between actions, information and material flows.
- Distinguish the value-adding activities from non-value activities.
- Easy understanding of the value streams and employees can identify the waste more easily.
- Improves the decision-making process of employees.
- Establishes priorities for improvement efforts.
- Focuses on no-cost or expensable improvements.
- Provides common language to talk about the processes.
- Is based on objective information.
- Forms the basis of an implementation plan.

In conclusion, the value stream mapping method can reveal several operational benefits if used properly. This method helps managers and other members of the organization to visually identify all the different links in the supply chain, and based on the current stat model, future improvements and suggestions can be made. For the lead time analysis this method is really useful, because it allows managers to focus aspects in the supply chain that are performing worst and by removing those bottleneck lead time can be shorten.

2.4.2 PDCA Cycle

The PDCA cycle, plan-do-check-act or Deming's circle, is an application used to continuously improve and search for better methods to improve processes. (Sokovic, et al. 2010) In addition, Westcott and Duffy (2015) mention that the plan-do-check-act cycle aims to constantly learn about the steps in the processes and use the knowledge to reduce the process variation and complexity and improve the total level of process performance.

The figure 12 under, illustrates the PDCA cycle in the rounded shape, which indicates to the continuous process of improvement. The first step is to plan, in which the problem is identified and analysed. After this, (do) the plan will be implemented. After this in the third phase, (check) the results of are analysed and monitored. And in the final phase, (act) the actions are made based on the results, if the results are satisfying no further actions are needed, but if the results are not reasonable, the plan has to be modified again. (Aggarwal & Lynn, 2012)

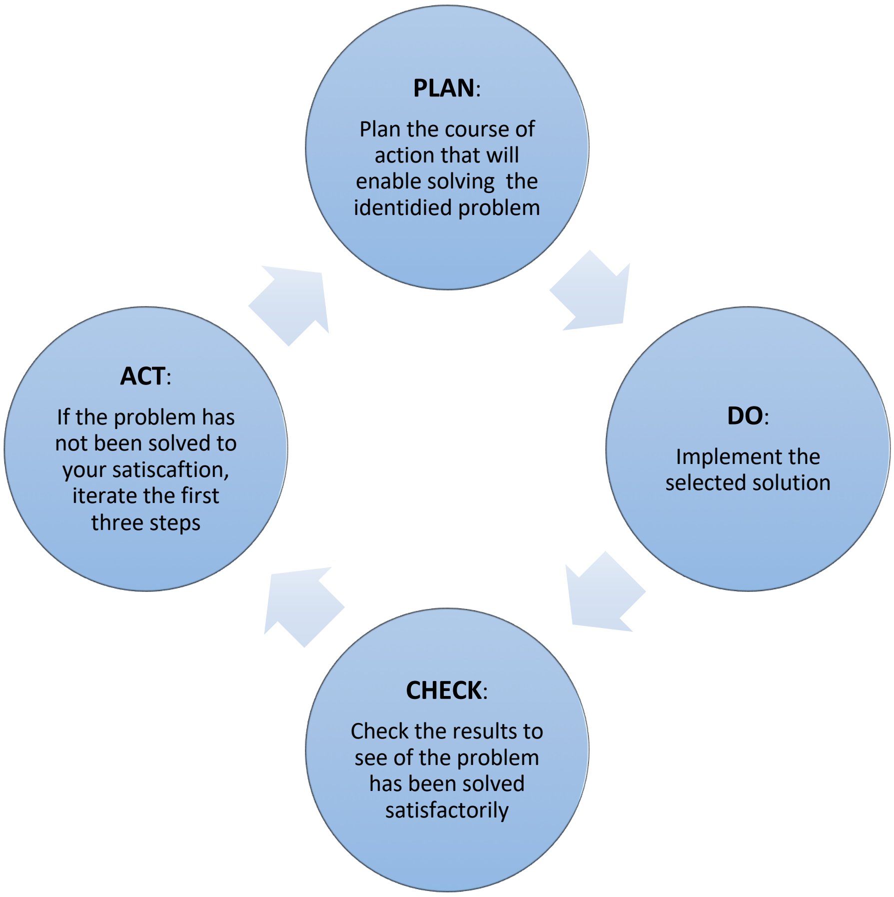


Figure 12. PDCA process (Adapted from Aggarwal & Lynn, 2012)

2.4.3 Kaizen & Just-in-time

Kaizen is a widely known method that refers to continuous improvement. (Myerson, 2012) The word “kaizen” comes from Japan and it means improvement. (Brunet & New, 2003) Kaizen was originally created to continually improve the processes by identifying and reducing waste (*muda*). In addition, by implementing the kaizen, companies are able to change the nature of work and reduce waste and other excessive work form the processes. (Chen, et al. 2010)

According to Bhuiyan and Baghel (2005) the continuous improvement in the organizations can occur through progressive improvements over time, or through radical changes that take place as a result of new technology or innovative idea. In addition, Bateman and Rich (2003, 186) mention that process improvements are usually shorter development projects and the continuous improvements take place over longer time period. Thus, companies can face both unexpected changes that emerge suddenly, and slow changes that has been created by the members of the organizations over a long period of time. Charron et al. (2015) provide a five-step model (below), to successfully implement the kaizen for the organizations.

Step 1: When a problem occurs, employee must report the issue.
Step 2: Evaluate the relevant information surrounding the problem.
Step 3: Take temporary countermeasures on the spot.
Step 4: Do the root cause analysis of the problem.
Step 5: Standardize to prevent recurrence.

Although, there is a large number of different type of problems among different organization and processes, but the core idea of the kaizen can be used to these situations. First, the problem has to be recognized and reported. After this, the temporary solution should be invented, and the root cause analysed. Finally, the process should be standardized and fixed so that the problem would not appear again. (Charron et al. 2015) Above all, kaizen is a business philosophy, that can be used to gain competitive advantage in the highly competitive business environment and manifest the idea of “there is always a room for improvement” in the companies (Smadi, 2009).

Like the previous kaizen approach, the just-in-time method also originates from Japan and was first used in the Toyota production called “kanban” system, to complete the orders as close as possible to the due dates (Sayer, 1986; Jósefowska, 2007). The just-in-time philosophy refers to the method, in which all the materials and products are available in the very moment when they are need in the production, not sooner or later, and in the right quantity. The target is to continuously improve and solve manufacturing bottlenecks inside the company and also solve the interface issues between companies in the supply chain processes. (van Weele, 2014, 246) In addition, Sugimori et al. (1977) mention, that the JIT production is a method to reduce the production lead time by having all the production parts in the right time at the right place with the minimum stock level to carry out the processes.

Although, the general assumption of JIT is to reduce the stock levels, many other benefits can be received through the proper implementation (Jósewska, 2007):

- improved product quality,
- shorter delivery times,
- better flexibility in production,
- better working environment for the employees,
- increased utilization of the workers capabilities, and
- good relationships with the suppliers, thus increased reliability of supplies.

To properly apply the just-in-time method, companies has to change both the culture and the manufacturing operations. (Walleigh, 1986, 38) Furthermore, Yasin et al. (1997) also emphasis that in order to gain the best possible benefit of applying the JIT, companies need to accept the method as a new organizational philosophy. Fullerton et al. (2001, 83) on the other hand cover, that the just-in-time method, is contrary approach to the traditional “push” system, where the JIT “pulls” final products through the system, only when orders are made. This “pull” system enable firms to operate with lower inventory levels and lower costs that are associated to the stock levels. (Kumar & Panneerselvam, 2007)

In the figure 13 below, the pull system is presented. The WS refers to workstation, and the figure tries to illustrate idea of the pull system, where each task is pulled by sequential workstations until the final product is prepared (stored). Moreover, the request for items (orders) illustrate the up-stream flow of information through the company, whereas items move down-stream to the store and ultimately for the final customers. (Kumar & Panneerselvam, 2007)

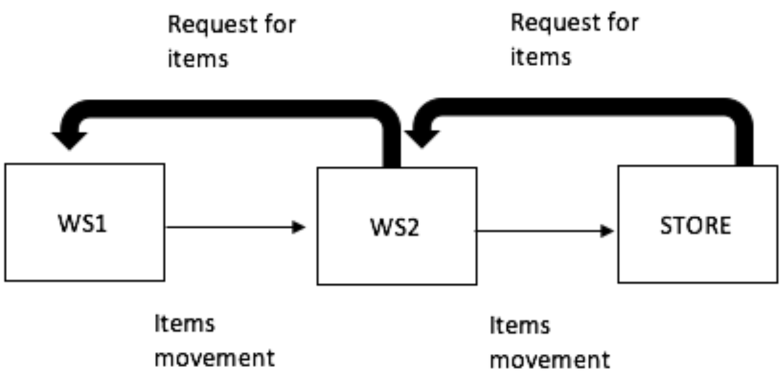


Figure 13. The pull system illustration (Adapted from Kumar & Panneerselvam, 2007)

Although just-in-time method has its roots deep in the manufacturing operations both in internal operations and supplier-customer relationships, the procedures and principles can be also transferred to an entire supply chain. JIT approaches that apply to the supply chain environment are for example lead time reduction, small batch production and product layouts. (Olhager, 2002) Furthermore, not all companies should pursue JIT method, especially those that are producing low-tech mass products for the end customers (Vokurka & Lummus, 2000). Thus, managers should understand whether or not to apply the JIT and if so to which processes the method is most suitable approach.

2.4.4 Failure mode and effect analysis

Failure mode and effect analysis (FMEA) is a structured method that lists the potential failure modes at one level and examine the effects on the other level. (Sharma, et al. 2005) The model was first introduced as a part of the US military procedures (MIL-P-1269) back in 1949, where failures were classified by their impact on mission success or staff/equipment safety. Later on, the approach was utilized in the car industry in the 1980s and until this day, implemented in several industries including aerospace, nuclear power plant, automotive, manufacturing and also health care sectors. (Zhu, 2017, 7)

The core idea of the FMEA is to identify and correct the potential failure problems during the design and production phases (Sharma, et al. 2005). According to Haapanen and Helminen (2002) the FMEA tries to answer for the following questions:

1. What could go wrong in the process or system?
2. How badly it could go wrong?
3. How to prevent these failures from happening?

The following five main phases of FMEA approach are illustrated in the figure 14 (Haapanen & Helminen,12, 2002):

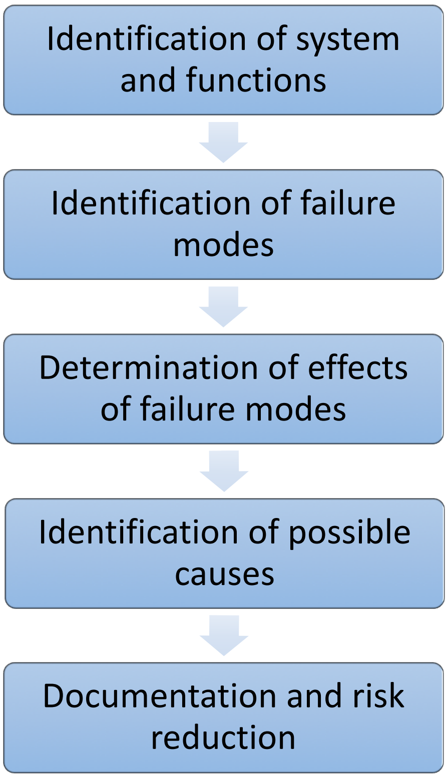


Figure 14. Main steps of FMEA (Haapanen & Helminen, 2002)

The FMEA process starts with the identification of the systems and functions that the method is used on. After this, the second step is to scope the potential failure modes in a progressive way. To identify the potential failure modes, the brainstorm technique has been useful method to this. After the second step, the effects and causes of the failures are determined in the next phases. In the final phase, the process is documented and actions to reduce the risk are taking the place. (Haapanen & Helminen, 2002) Furthermore, Sharma et al. (2005) identified a ten-step program of carrying out the FMEA process. These ten steps are the following:

1. Identify and illustrate the system to be analysed.
2. Make a block diagram of the system.
3. Determine potential failure modes and the effects.
4. Evaluate the failure modes in terms of the severity.
5. Identify methods to detect the failures.
6. Estimate the probability of occurrence (S_f).
7. Calculate the risk priority number (RPN), by using relation RPN = $S_f * S * S_d$.
8. Estimate the RPN number and make actions according to it.
9. Summarize the FMEA report to the table form (shown in the table 5 below).

The FMEA table format can be seen in the table 5 below. (Sharma et al. 2005) This table format helps to list and detect the most important failure modes in different process steps, items or functions.

FMEA													
System							**FMEA No.**						
Subsystem							**Page.**						
Component							**Prepared by**						
Core team							**FMEA Date (org.)**						
									Action results			(Rev)	
Item/function	Potential failure mode	Potential effects of failure	Severity	Potential causes of failure	Occurrence	Current design controls	Detect	Recommend actions	Actions taken	Severity	Occurrence	Detect	RPN

Table 5. FMEA table format (Sharma et al. 2005)

2.5 Lean Six Sigma

First in this chapter, we will discuss about Six Sigma topic. After that we will move to the lean Six Sigma theme. Both Six Sigma and lean Six Sigma are closely similar themes, but it is good to understand the minor difference between these two approaches and how these two methods have evolved.

2.5.1 Six Sigma

According to Linderman et al. (2003) the concept of Six Sigma originates from USA in the 1985 and was first introduced by Motorola company, which was designed to respond for the increasing competition in the electronics industry by making major improvements to the product quality levels. According to Myerson (2012) the Six Sigma is a strongly statistical tool that aims to remove defects and variability from each process step. In addition, Linderman et al. (2003) mention that the Six Sigma is a systematic method for strategic process improvements and new product and service development that is based on statistical and scientific methods to make reductions in defect rates, determined by the end customers.

Furthermore, Antony and Banuelas (2002) mention, that the key for success of using the Six Sigma method is the step-by-step approach of using define, measure, analyse, improve and control methodology for the business processes. These five DMAIC process steps in the Six Sigma approach are used to tackle specific problems in different business processes. The target Sigma level indicates what is the desired process performance level for the customers. Higher Sigma level, indicates more pressure from the customers which creates more pressure to the company, e.g. more resources and costs needed to satisfy demand. These five phases are the following (Thomas, et al. 2009; Breyfogle, 2003; Myerson, 2012):

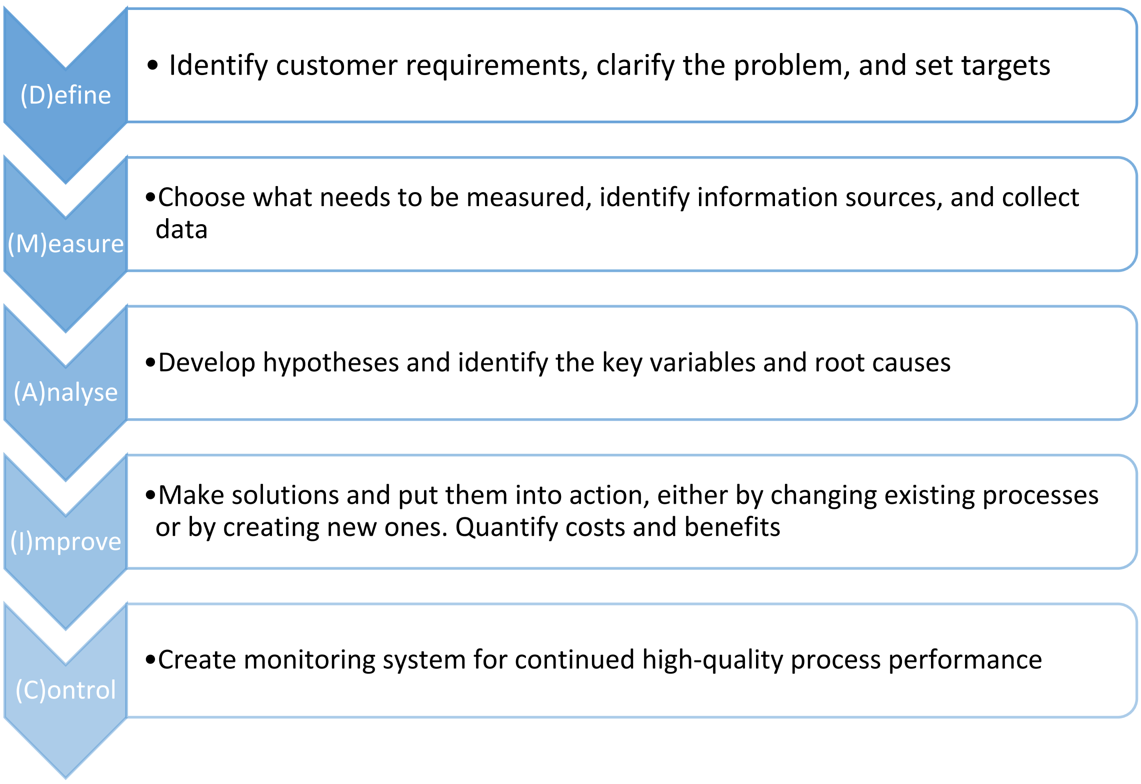


Figure 15. Six Sigma process steps. (Adapted from Thomas, et al. 2009; Breyfogle, 2003; Myerson, 2012)

Furthermore, the figure 16 below, illustrates the Six Sigma model in the supply chain contexts. This framework model shows how the DMAIC steps can be attached to the different supply chain steps and the process improvements can be targeted depending on the desired project or improvement areas. For example, if the firm concentrates on the manufacturer and distributor link, because there are some unidentified bottlenecks in that link, the Six Sigma project and measurements should be targeted to that part of the supply chain by defining, measuring, analysing, improving and finally controlling the link. In that way the company can detect and remove bottlenecks from the process and improve the overall performance of supply chain process.

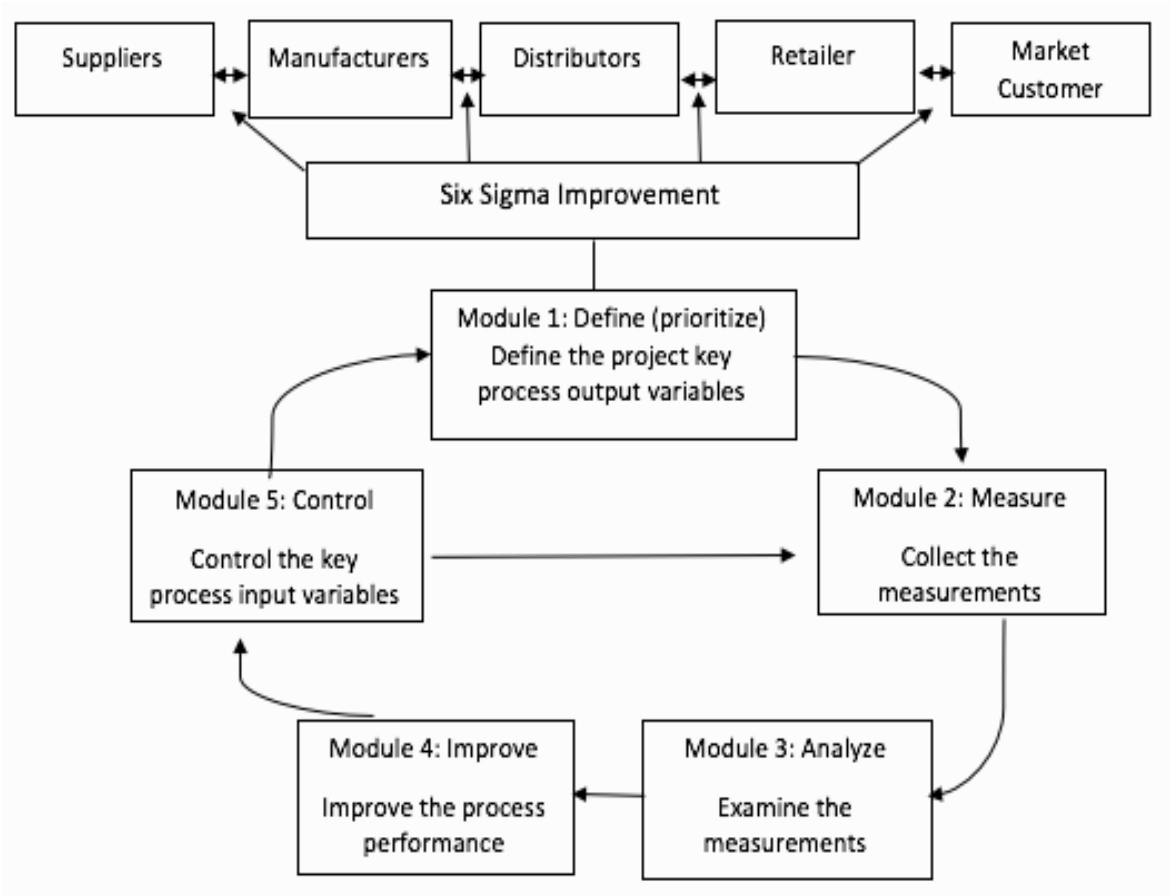


Figure 16. Framework of Six Sigma in supply chain network (Adapted from Wang et al. 2004)

To understand the statistical characteristics of the Six Sigma method, Linderman et al. (2003) provide a graph to illustrate this mathematical nature. In the figure 17 under, the defect rate (defects per million opportunities, DPMO) is plotted against the process Sigma level by using different Sigma levels. The graph illustrates the relationship of how many defects the system can tolerate in these six different process Sigma levels, assuming the normal distribution. For example, if the target process Sigma level is Six Sigma (3,4 DPMO), and 99,99966% process yield (these computations assume a 1,5 S.D. shift in the process mean) the goal is quite hard to accomplish and will require lots of effort and resources from the company, whereas if company only targets process Sigma levels of two or three which are relatively easy and cost efficient to achieve. Thus, it is important to consider the benefits and sacrifices, about how important the process is and how high level of process Sigma should be targeted. (Linderman, et al. 2003) Naturally, higher Sigma level requires more resources and costs from the company, whereas lower Sigma levels can be achieved with lower effort.

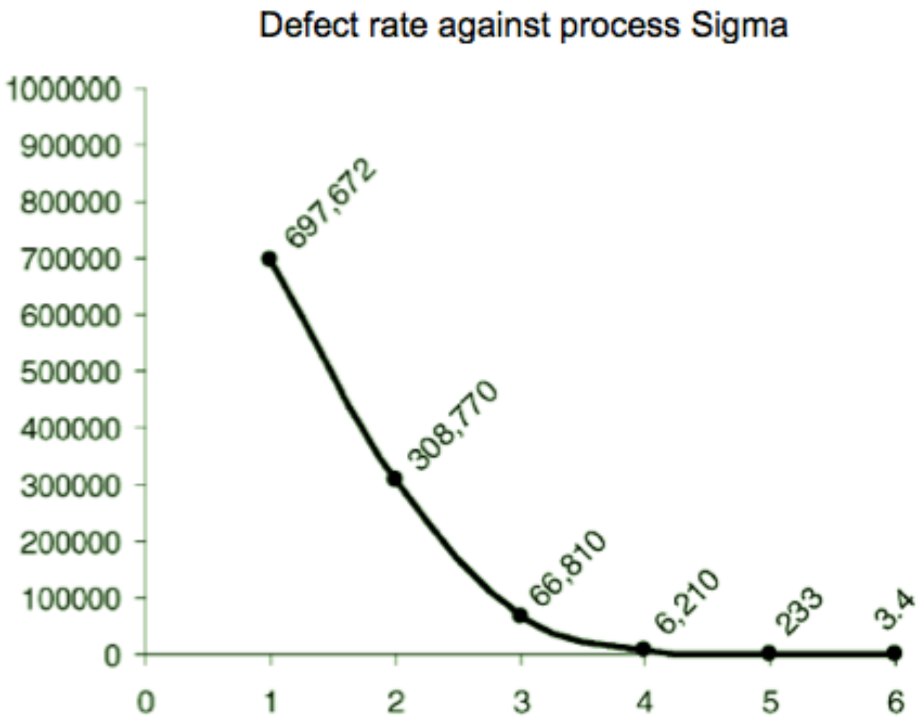


Figure 17. Defect rate against process Sigma levels (Adapted from Linderman et al. 2003)

Furthermore, the table 6 below, demonstrate the Six Sigma concept by listing the specification limits, inside specification percentages and defects per million opportunities to a table. This table illustrates the same thing as in the figure 16 above, but it helps to visualize the different process Sigma levels (from one to six) and what different requirements are in those limits. The inside specification percentage refers to how much (in percentage) the certain process is free of defects, meaning that if the target Sigma level is for example three, the process should be 93,32% free of errors etc. (Myerson, 2012, 16).

Specification limit	Inside specification	Ppm defective
+/- σ	30,2300 %	697700
+/- 2σ	69,1300 %	608700
+/- 3σ	93,3200 %	66810
+/- 4σ	99,3790 %	6210
+/- 5σ	99,9767 %	233
+/- 6σ	99,9997 %	3,4

Table 6. Six Sigma concept table (adapted from, Wang, et al. 2004, 1219)

2.5.2 Lean Six Sigma

By combining lean with Six Sigma comes the “lean Six Sigma” concept, and like Byrne et al. (2007) mention, the lean Six Sigma approach draws on the philosophies, principles and tools of both methods. Furthermore, the optimal solution would be to combine these two approaches, because lean provides tools for the total system approach and Six Sigma provides a general analytic framework for problem solving and organizational structure analysis. (Koning et al. 2006) Additionally Bhuiyan and Baghel (2005) mention that lean and Six Sigma methods individually cannot reach to the required improvement levels as the hybrid version can. Thus, a comprehensive approach would help companies to link the benefits of the two methods to both organizational and process improvements.

As discussed earlier, the lean method aims to improve process flows by reducing waste and the Six Sigma strive to reduce the process variability and defects from the processes. The figure 18 below, combines the objectives of both lean and Six Sigma methods. In addition, as shown in the figure, both methods can be also combined in order to reduce waste, non-value-added work and also shorten the process cycle times (Snee, 2010). Thus, it is clearly important to understand that these methods can also be used as combined lean Six Sigma to increase business performance and solve complex problems by using the hybrid approach.

Furthermore, the combination of these two methods, can be used in the supply chain context quite naturally, because the lean aims to maximize the process flows in the supply chain by reducing waste and non-value adding processes and the Six Sigma strives to improve processes by understanding the customer needs and using statistical tools to remove variation from the supply chain activities. In addition, Antony et al. (2003, 42) mention that when the Six Sigma is combined with the agile and fast lean principle, it will produce solutions for better, cheaper and faster business processes.

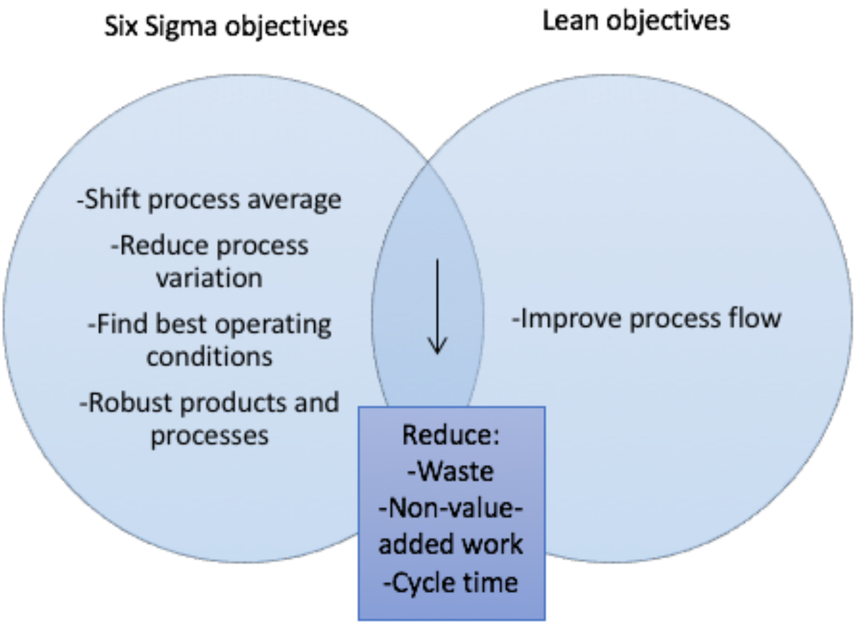


Figure 18. Improvement objectives of lean and Six Sigma (Adapted from Snee, 2010, 14)

Like the previous Six Sigma method, the lean Six Sigma doesn't have a generally accepted definition or a common model behind its back. And quite often the combination of these two models are seen just a "philosophical" or nearly religious model, which is lacking the practical foundation of the holistic approach (Bendell, 2006). Snee (2010) defines the lean Six Sigma as a business strategy and methodology that increases the process performance, which ultimately leads to improved customer satisfaction levels and financial results. In addition, Salah et al. (2010) cover that the hybrid concept focuses on improving financial results, satisfying the customers and also improving business processes. For this multidimensional lean Six Sigma concept, Pepper and Spedding (2010) offer a conceptual model to represent the combined relationship between these two models. This combined lean Six Sigma model is presented in figure 19 below.

The figure 19 indicates that the lean philosophy can be seen as the core foundation of the business process improvement. Following this, after the key areas or "hot spots" for the improvement have been identified, the Six Sigma provides a specific project-based system approach to remove these issues or bottlenecks form the system. This can ultimately lead the system towards the desired future state, where the process performance is higher than before. (Pepper & Spedding, 2010)

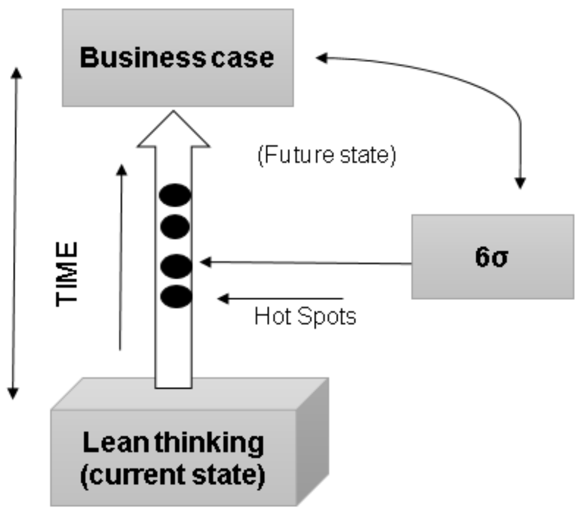


Figure 19. The lean Six Sigma conceptual model (Adapted from Pepper & Spedding, 2010, 150)

The relationship between both lean and Six Sigma steps is illustrated in the figure 20 underneath. The define phase, emphasis the understanding and analysis of what is valued by the customers. Lean mapping of current stage refers to measurement and analysis of the baseline situation and the possible improvement ideas can be formulated and analysed further. In the improvement stage, the process is adjusted to make the value flow run in more efficient way than before by using future state mapping and introducing the pulling concept. Finally, in the control phase, the process is perfected by using controls and procedure to ensure process improvements and this is done in the continuous manner to ensure future success. (Salah, et al. 2010) This figure clearly clarifies the relationship with lean and Six Sigma approaches and that the combination of these models can be applied to the business context.

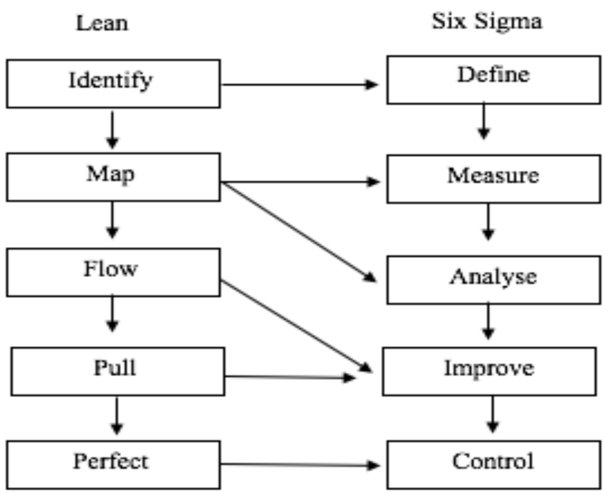


Figure 20. Phase relationship with lean and Six Sigma (Adapted from Salah, et al. 2010)

In conclusion, these two process improvement tools and methods can and should be kept together. As the lean method refers to more cultural aspects of process improvements by combining the entire organisation with the philosophy, the Six Sigma addresses the improvement areas with more data driven and numerical methods. Thus, these two different approaches should be combined to one lean Six Sigma method. Furthermore, not all companies or business situations should pursue the lean Six Sigma or one of the methods individually, rather firms should understand the idea of these two approaches and find possible aspects or tools to be implemented for the company purposes. (Pepper & Spedding, 2010)

3 EMPIRICAL CASE STUDY

In this third part of the study, the empirical research is conducted and analysed. First in the chapter the research material and methods are presented and discussed. After this, follows a brief case company and product presentation. Following this, the current situation of the supply chain capabilities will be introduced in the sub-chapter 3.3, and finally at the end of this chapter the interviews and FMEA survey are being analysed.

3.1 Research methods and material

As discussed in the first introduction chapter, the study will be conducted as a qualitative single-case research method that uses a real-life case-company material to form the basis of the research. The case material is provided by the Finnish manufacturing company F. Additionally, Halinen and Törnroos (2005) cover that the main idea of case research method is to give multidimensional view of the situation to be examined. In this light, the case study will give a profound and wide view of the research situation, which also allows researcher to deepen to the phenomenon in question and form better analysis of the matter. To better understand the case research process, Stuart et al. (2002, 420) provide a basic five steps model to illustrate these stages of the research process (in the figure 21 below).

Figure 21. Research process model (Adapted from Stuart et al. 2002, 420)

The research process starts with defining the research questions and building the literature review for the study. This beginning phase will give a solid preunderstanding of the topic and possible research gaps can be found based on the exploration of the current academic literature. (Kähkönen, 2011; Stuart et al. 2002) The second stage is the instrument development. This step incorporates the main documentation needed to provide the researchers with the needed focus, visit organization and also ensure that the evidence trail is comprehensively documented. The third step is to gather the necessary data. This data is usually taped or written records of the interview, company documents and observations by the researcher. After this comes the fourth step, where the data is analysed, which can be seen as a process of finding and understanding the relevant information from the large amount of data. Finally, the fifth step is to report and disseminate the results and also address the valid criticism to the chosen methods. (Stuart et al. 2002)

The study uses a company data and observation as a main source of empirical information. Furthermore, the secondary data will be collected by doing interviews and FMEA survey. This allows the researcher to gain more versatile information of the situation and to implicate the company internal/employee perspective to the matter. One of the key advantages of using the case study as a research method is that it allows to use and analyse both qualitative and quantitative data (Zainal, 2007). Also, in this particular study the author will use both numerical and non-numerical data to form a comprehensive understanding of the matter in question.

3.2 Case introduction

First in this chapter, the case company will be introduced. Following this, the case product will be shortly presented. Finally, at the end of this sub-chapter, the initial situation for the study will be discussed briefly.

Company presentation

Case company F is a Finnish manufacturing firm that is known for its reliable industrial solutions especially for demanding and harsh process conditions. The company supply its products world-wide and was first founded in 1977 with the original company name Larox Oy. After that several years later, in 2011 the company changed its name to company F. The company has its head office in Lappeenranta and branch office in Kouvola. Furthermore, the company has several subsidiaries; in Maryland (USA), Sidney (Australia), Johannesburg (South Africa), Moscow (Russia) and Shanghai (China). (Company F, 2018; Company F, 2016)

The company is specialised to deliver its product to several different industries e.g. mining and metallurgy, cement and construction, energy and environment, water and wastewater, chemical process industry, oil and offshore, pulp and paper and food and pharmacy industries. Some of the most distinguished products that the company supplies are the valves and pumps for different industrial purposes. Furthermore, the company also provides additional products and services, and also new smart solutions (Industrial Internet of Things) for the various industrial purposes. (Company F, 2016)

Product presentation

The main research question for the study was: *"How the global supply chain performance can be improved for the case product?"* In this light, the research tries to find possible solutions to increase the supply chain performance for a one particular product, which in this case is the Packaged Pumping Systems (PPS). The product is designed to serve various different industries like for example; mining, water and wastewater solutions, steel, fertilizers, cement, power plants, various chemical processes etc.

The biggest benefit of having the product is that is has been designed to be more compact, easy access, fast installation and low-cost solution for the different industrial purposes. In addition, the product is designed to be easily customized, low maintenance, safe and durable pump system. In the figure 21 below, the product (simplex version) is visually presented. The product is also available as duplex (two pumps), triplex (three pumps) and quad (four pumps) models, regarding the different customer needs. Furthermore, the flexibility of the system gives the customer the freedom to install the system either on the floor or on the wall depending on the production requirements. (Company F, 2018)

Figure 22. A picture of the Packaged Pumping System (Company F, 2018)

<u>Starting point for the empirical research</u>

The need for the research originates from the case company. The starting point for the study was that the company launched PPS to the North American markets in 2017. The problem was that the company had serious issues with the supply chain lead times. For this reason, the purpose of the research is to find improved solutions for the supply chain lead times, in other words, to make the supply chain operations more efficient with the lowest possible costs. Thus, the idea is to build/form a more efficient supply chain for the product, so that the product can be also distributed into the global markets more efficiently with shorter supply chain lead time.

The company aims to deliver the case product between three to four weeks of time, which means that the company supplies its products from the order request to the customer delivery with maximum of three to four weeks depending on the delivery contract. Furthermore, the previous statistics indicate that the average lead time for the PPS was close to nine to ten weeks. Thus, it is clear that the company needs to find some improved solutions for the current supply chain operations. In addition, as the case product is relatively complex, due to the different customer customizations and design, and also the forecasted sales are quite small for the product (around 200-500 pcs per year), which also creates pressure to supply chain operations (ability to reach the intended delivery time), while having the lowest possible operational costs (e.g. low stock-level and operating capital, etc.).

3.3 Current situation analysis

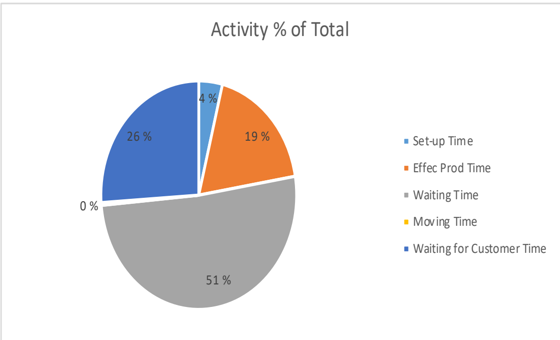
In this part of the thesis, we will discuss and analyse the current state of the supply chain activities. As discussed earlier, the long lead time in the supply chain processes has been one of the main issues in the operational performance for the company. The following table 7, provides some useful information of the previous lead times (from year 2017). This data refers to the supply chain lead times when the work is completely done in house and not by the company subcontractor. The company has also additional information of the supply chain lead times when the work is done by the company subcontractor, but in this study, we are only handling the situation in which the work is done inside the company.

The entire supply chain process (in table) has been divided into five different phases from order management to delivery step. For these different supply chain steps, each column informs different durations/time depending on the activity. For example, the table shows how much "set-up time" each of these five process steps include, which appears to be 18 hours in total; by engineering (10 h) and delivery (8 h).

Summary

VCM (Packaged Feed Systems) - All work done inhouse

	Set-up Time	Effec Prod Time	Waiting Time	Moving Time	Waiting for Customer Time	Total Time	Phase % of Total		
Order Management	0	2	24	0	0	**26**	6 %		
Engineering	10	31	80	0	0	**121**	26 %		
Approval	0	8	0	0	120	**128**	28 %		
Fabrication Prep & Procurement	0	20,5	96	0	0	**116,5**	25 %		
Delivery	8	23,5	36	1,75	0	**69,25**	15 %		
Totals	**18**	**85**	**236**	**1,75**	**120**	**460,75**		**61,43333333**	**9**
Activity % of Total	4 %	18 %	51 %	0 %	26 %			Working days	Weeks



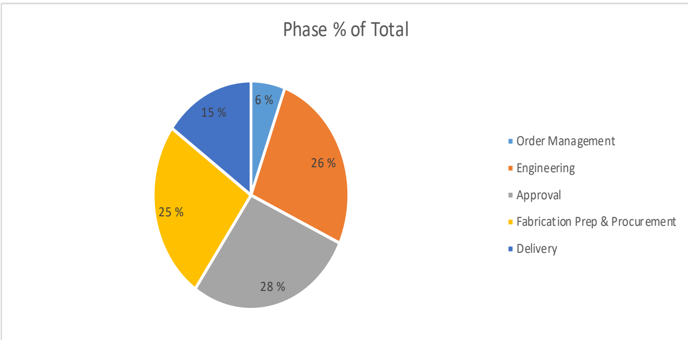


Table 7. Information of the supply chain lead times (work is done in house)

The table 7 also indicates that the most time-consuming activity has been the “Waiting time” with total of 236 hours required (51% of total activities) as the left-hand side graph indicates. Furthermore, the “Waiting for customer time” is the second most time-consuming activity with total of 120 hours required (26%). The remaining three activities; “Effective production time” (85 hours, 18%), “Set-up time” (18 hours, 4%) and “Moving time” (1,75 hours, 0%), were not significant compared to the other two activities.

Additionally, the right-hand graph provides information about how much time each process step requires. This diagram indicates that the approval process is the most time-consuming process step in the supply chain (128 hours, 28%). The second and third most time-consuming steps are the engineering (121 hours, 26%) and the fabrication preparation and procurement process steps (116,5 hours, 25%). The delivery process (69,25 hours, 15%) and the order management (26 hours, 6%) are contributing least on the supply chain lead time. The following table 8 under, lists the activities and the process steps from the most time consuming to least time consuming.

List of activities (time required)	List of process steps (time required)
1) Waiting time: 51 %, 236 h	1) Approval: 28%, 128 h
2) Waiting for customer time: 26%, 120 h	2) Engineering: 26%, 121 h
3) Effective production time: 18%, 85 h	3) Fabrication preparation & procurement: 25%, 116,5 h
4) Set-up time: 4%, 18 h	4) Delivery: 15%, 69,25 h
5) Moving time: 0%, 1,75 h	5) Order management: 6%, 26 h

Table 8. Summary of activities and the process steps in the supply chain

Additionally, the table 7 also indicates that the average lead time for the PPS has been almost 62 working days, which is approximately 9 weeks. As discussed earlier, the company aims to complete the delivery process between 3-4 weeks, so there is definitely room for process improvements in the supply chain activities and cut down the lead time with close to 5-6 weeks in order to reach the target lead time.

The following table 9, summarizes the main advantages and disadvantages, and also possible suggestions for the improvements and the results of these improvements when the work is done by the company F (in house). This following table is provided by the case company (excel-file), and the author has not been modifying the table content.

IN HOUSE	
Advantages: ▪ Control of the processes ▪ Flexibility ▪ Gaining service capabilities ▪ Overlapping process opportunity	***Disadvantages:*** ▪ Lack of resources (engineering & assembly) ▪ All risk lies with Company F ▪ Component pricing higher due to volume ▪ Way customers view custom system as cheaper ▪ Volume = production efficiency
Possible improvement suggestions: ▪ KA & BOM verification to take place ▪ Run KA prior to release for procurement ▪ Sticker QC at inbound logistics ▪ Tool requirements to be identified during design and picking ▪ New PVC pipe cutting tools identified ▪ Use thicker back plate & no standoff blocks ▪ Create IOM's for PFS ▪ Identify critical parts to be kept in stock ▪ Standardize test procedure & setup ▪ Implement new method for fix leaks ▪ Do pressure & 24-hour test measurement using the Malibu	***Results from improvements:*** ▪ Minimize delay downstream due to incorrect BOM ▪ Ensures all required parts are procured and lead time optimized ▪ Minimize problems downstream ▪ Minimize problems downstream ▪ Will improve quality & efficiency of cutting process ▪ Will reduce assembly time ▪ Improve aftersales service, eliminate need for custom IOM's for each project ▪ Minimize delays during assembly due to re-work ▪ Minimize rework time ▪ Record more useful data, more professional test reports

Table 9. Summary of the in-house solution (Company F, 2018)

Value stream mapping

As discussed earlier in the theoretical section, the value stream mapping can be a useful tool for companies and managers to identify possible bottlenecks and create suggestions for the supply chain improvements. Value stream map is a lean based tool to identify waste and add value for the final customers. In this light, the current state map is created to represent the overall supply chain structure of the case product and to illustrate the different steps in the value chain. Furthermore, by using the value stream mapping, also the process times can be shown from the map, which helps to detect the most time-consuming processes from the supply chain. The following figure 22, represents the value stream map for the Package Pumping Systems (current state).

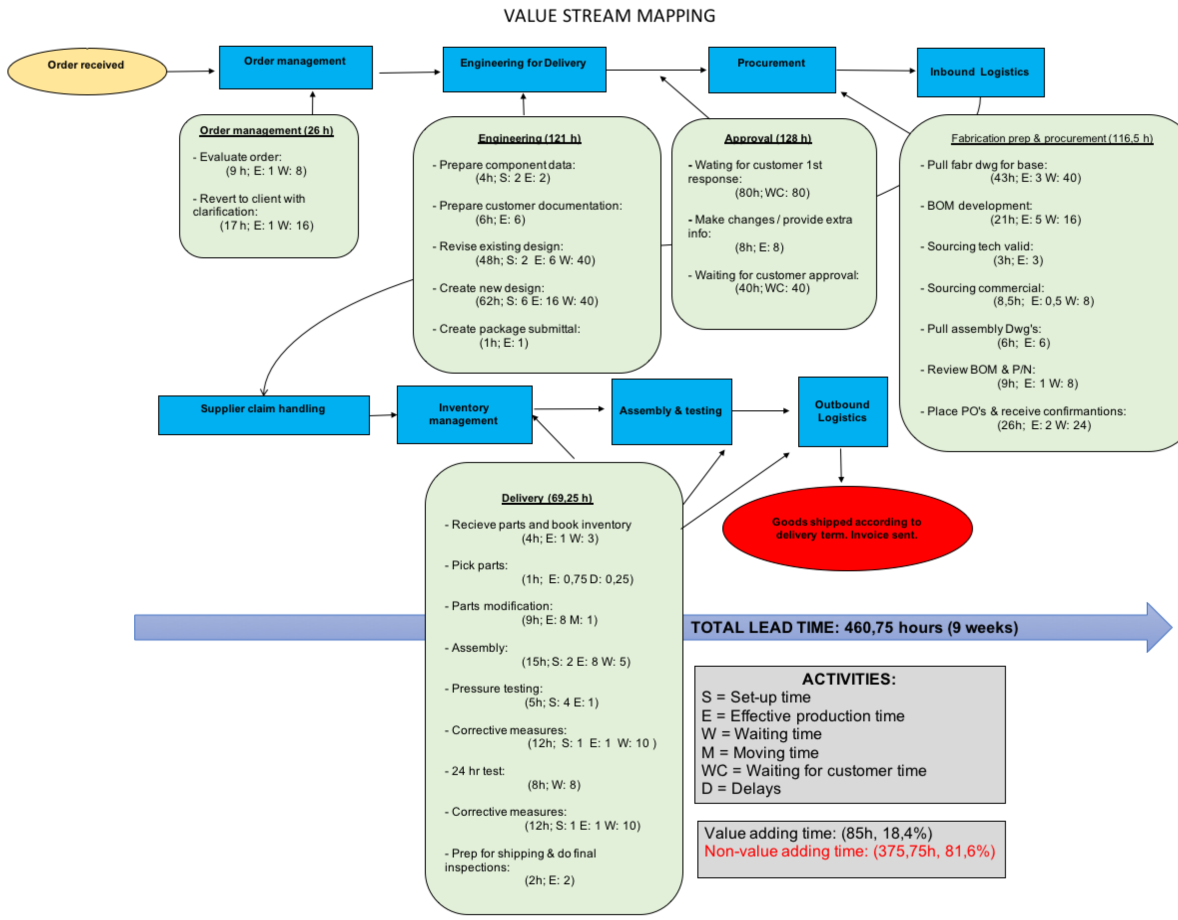


Figure 23. Current state value stream map (work done in house)

The entire supply chain process has eight different process steps (marked in blue). The order received is the first activity in the supply chain process, where the customer order is received by the company. This is linked to order management, that is the first main step in the supply chain process, where the order request will be processed and evaluated by the company personnel. After this comes the engineering for delivery step. This is a critical step, because the product coding, design changes, the possible product modifications, customer documentation, package submittal creation and the order approval will take place. Hence, for example if some wrong information about the product design passes through the steps, in worst case the customer will have wrong type of product which may lower the customer satisfaction and increase costs due to the new product design and delivery compensation.

Following this, comes the procurement process. In this phase, the drawings will be formed, components sourced, and also other additional procedures will take place to properly place the procurement and prepare the fabrications for the production. After this, comes the inbound logistics step, which entails different activities concerning procurement and logistics activities. Following the inbound logistics step, comes the supplier claim handling phase and before this there can be close to two weeks waiting time to anticipate the supplier approval. Right after the supplier claim handling process comes the inventory management phase. This step incorporates activities such as receiving parts and booking inventory, picking up parts and making modifications to the parts. After the inventory management step comes the assembly and testing phase, which incorporates for example; product assembly, pressure testing, corrective measures and the 24-hour durability test for the pump. Finally, in the supply chain comes the outbound logistics step, where the order is prepared for the shipping with final inspections and providing the shipping documentations. After the outbound logistics step is completed, products will be shipped according to the delivery terms (International Commercial Terms) and the invoice will be sent for the final customer.

The total lead time on average to complete the delivery process (from order received to products shipped) takes 460,75 hours, which is approximately 9 weeks. For those activities involved in this supply chain process, value adding time is only 85 hours (18,4%) of the total activities and the remaining time is considered to be non-value adding time, which is the remaining 375,75 hours (81,6%) of the total activities. For this analysis, only the “effective production time” (E in the value stream map) is considered as value adding time, and the remaining activities (S = set-up time, W = waiting time, M = moving time, WC = waiting for customer time and D = delays) are all handled as non-value adding time. Value adding time can be seen as an activity in the supply chain that “add value” to the product or service in the eyes of the final customers. Thus, the value stream map shows that there is a lot of room for waste reduction and process improvement in these current supply chain operations.

Furthermore, as shown in the value stream map, the most time-consuming process areas of the supply chain are; approval (128 hours), engineering (121 hours) and fabrication preparation and procurement (116,5 hours) processes, but the approval process involves most of the time (120 hours) “waiting for customer time”, so company F cannot fully control or manage that process phase, because the approval process relies mostly on the supplier’s actions. This also is why most of the supply chain improvement actions should be targeted to the engineering and fabrication preparation and procurement processes. Furthermore, the link between the engineering for delivery and procurement is the most important segment in the supply chain operations, so most of the improvements should be targeted to that area. The following figure 23, summarizes the two most important process steps in the supply chain activities (Engineering for delivery and procurement) for the case product and highlights the different activities in those steps. Additionally, the approval process lies in between these two process steps, but like previously mentioned, most of the time (120 hours) only the supplier can have impact to the lead time. Thus, the company should probably concentrate on the engineering and fabrication preparation and procurement processes and allocate the improvements to those process steps.

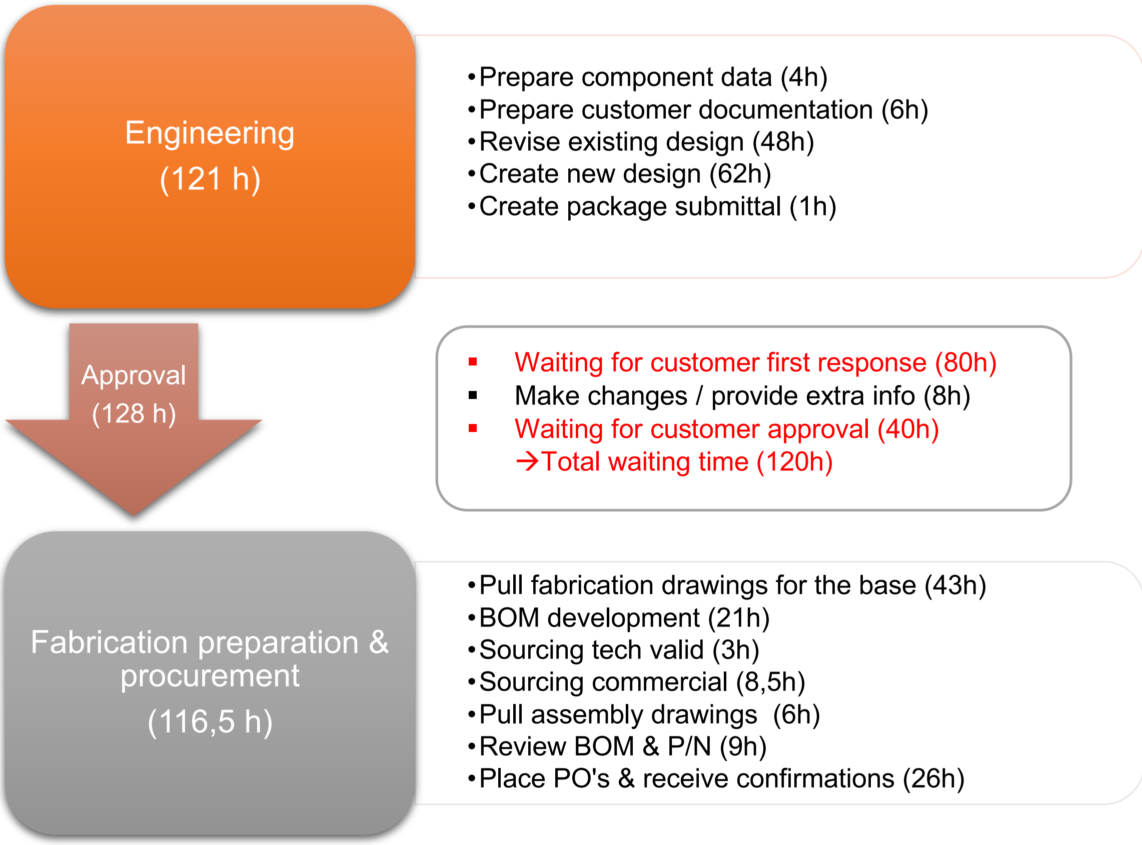


Figure 24. Summary of the most critical section of the supply chain

To fully understand the big picture of the supply chain processes, the following figure 24 below, provides visual information about the company F's procurement activities. This procurement process is also one of the main processes in the supply chain operations for the company and also one of the two most critical processes in the supply chain activities (in figure 23). The procurement process is divided into five different layers, where different personnel/systems are responsible of the procurement process flows. The bottom part (IT

Applications) refer to company ERP system, which stores and administers the relevant data for the procurement process and other company purposes. A functional ERP system is a really important aspect of the company success, because it connects different functions and personnel from the same system and store large amount of data to provide information for various business purposes. Following this, comes the sourcing manager who controls and manages the sourcing process. In addition, the sourcing manager is responsible for searching new alternative suppliers if there is no existing supplier available for the product, and also most of the information regarding the procurement process flows through the sourcing manager.

After this, in the middle part of the figure is the order handler, who handles orders by receiving the order requests and controlling the necessary information regarding the order process. Following this, comes the procurement specialist, who places orders and interacts with the suppliers in the daily basis. This is a crucial position, because the person who acts as a procurement specialist act as a link between the suppliers and the company and most of the information flows through the procurement specialist. Finally, there is the supplier, who receives the purchasing order and confirms the final order to the procurement specialist. So, all of these individuals and systems are involved in the procurement process which consists of many different steps; from the decision to buy/purchase to complete the entire sourcing process. Thus, the efficient flow of information especially in the procurement process will help companies to coordinate the supply chain systems and to lower the risk of making mistakes in the supply chain operations. Furthermore, by having a functional procurement process companies can save a lot of money and time and enhance better quality, which ultimately improves the customer satisfaction level and company financial position in the markets.

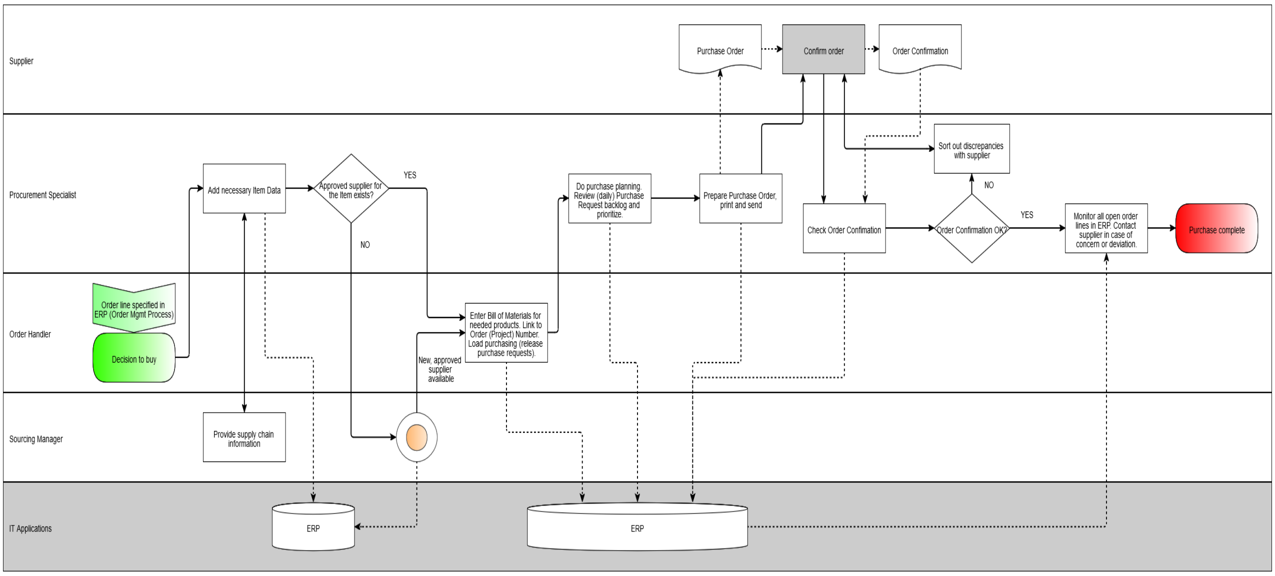


Figure 25. Map of the procurement process by company F.

3.4 Interview Analysis

The interview used in the research consists of two themes (shown in appendix 1); current level of supply chain processes and future state of supply chain processes. For these two themes, total of 12 questions were developed. The interview was conducted by having two separate semi-structured interviews (face-to-face interaction) in the company F's premises. The first interviewee works as a product development manager in the company (E1: in the analysis), and the second interviewee works as a technical procurement specialist in the company (E2: in the analysis). Both of the interviews were recorded and after that transcribed and analysed. The results of the interviews will be presented in the following subchapter (3.4.1 & 3.4.2).

3.4.1 Current level of supply chain processes

In order to understand the current situation of the supply chain processes the interviewees were asked to describe the current state of the supply chain processes for the case product (Package Pumping Systems).

According to the interviewee E1, the current supply chain operations for the PPS are located in the USA and the TuffSkid company (supplier) makes and deliveries these products for the company F in a way that most of the products are just being assembled in the company

F’s plant, and then shipped to the end customers. E1 also emphasized that this has been in the beginning phase one of the company targets, because sales volumes were relatively small, and thus it would be better to let companies like TuffSkid to supply these products, because they are specialized in providing these parts and components and company F can just assemble these different parts, which also allows company F to focus more on the core business competences. Concerning the same question, the interviewee E2 mentioned that the long supply chain lead time has been the biggest issue for the case product and it therefore reduces the overall sales of the PPS. Furthermore, E2 also covers, that it would be desirable to lower the cost structure for the product to make it more profitable, because the profit margin could be higher.

In the second question, the interviewees were asked what factors may have had the most influence for the long supply chain lead time. For this, E1 mentioned that usually there has been some issues in the lead time management when the product has been more customized for the customer preferences. And because of this, company F has had to look for new alternative suppliers for the product. For the same question, E2 responded that as the supplier has been controlling the product/component (the skid) in the supplier side, which means that the company F has less power for the delivery terms, and it has been one of the issues in the supply chain operations. E2 also claims, that it would probably be better for the case company, if the skid base (see appendix 2) would be designed and controlled in house, and not relying solely on the supplier models. E2 also mentioned that the current demand forecasting for the product is quite hard, but by increasing the sales volumes and having some rough estimations for the future sales, e.g. 100 or 500 units per year, it would also increase the customer-value of company F in the eyes of supplier, which could ultimately lead win-win situation for both companies (supplier and buyer) in the long run, because the supplier could see the company F more valuable customer based on the purchasing quantities. E2 also mentioned that as far as he knows the product might be too complicated, meaning that there are too many variations of the product (duplex, triplex, quad etc.) and E2 would change the skid base so that it would be more modular for the different customer requirements. This modularity would increase the usability of the product so that the same skid bases could be combined/stacked with other same size skids if necessary.

In the third question, the interviewees were asked that whether these factors (mentioned in the second question) are also generalized for the other products that the company is manufacturing. E1 mentioned that although company can have occasionally some issue in the lead times in some other product categories and segments, usually these are better known beforehand, because some electric actuator with special voltage can have delivery time up to two months and the delivery time is also know in the customer side, so that is not so big issue. E1 also cannot directly say why the lead time is so long for the product and emphasizes that it would be appropriate to use standard packages for the product and this would allow to keep couple units of the product in the stock. E1 also said that the skid base may be the biggest challenge in the supply chain, because other components in the product are so standard (plastic pipes, couplings etc.) and they can be sourced in a couple of days.

For the question three, E2 responded that in general new products are challenging for the company. According to E2, if the product has a long lead time, the company intend to use intermediate storages either in the company premises or in supplier warehouse, but the endeavour is to use the supplier stocks. Interviewee E2 also emphasis that long delivery times are issue because they are directly related to the sales. In other words, company delivering the same type of product with shorter delivery time win the bidding for itself, so delivery time is a source of competitive advantage in the current competitive markets. E2 also state that he doesn't know how close the price competition is with these type of pump products, but he claims that in general the price competition is relatively close with other products that the company F is currently manufacturing. Thus, according to E2, the delivery lead time can be seen as an important factor when making buying decisions and choosing the right manufacturer for the pump system.

In the fourth question, the interviewees were asked about, what are the main issues these long lead times are causing for the; company F, customers and other company stakeholders. For this, E1 responded that if it is known that there is a long delivery time for the product, it won't promote the sales for the product, and unless the price of the product is not significantly lower than the competitors corresponding, shorter delivery time gives the other rival "1-0" advantage over the company F due to the delivery speed. E1 also emphasized that the product delivery has to be consistent, which means that whether the delivery promise is 4 weeks or 10 weeks the promise must be kept. Furthermore, E1 also mentioned that if the delivery promise is not met, due to the longer delivery time (delay), it will lower company F's customer value and the same customer probably won't purchase next time from the case company. In addition, the interviewee E1 saw that most of the disadvantages of the long lead time, are only associated to customers and company F, but also mentioned that if there is a middleman in the delivery chain, this (middleman) may also have to explain the situation if the delivery time is over the agreed date.

For the same question, E2 responded that the company F should probably use larger stock levels, which also increases both inventory levels and costs, and that company F loses some of its sales due to the longer lead times. On the other hand, E2 mentioned that for the customers the long delivery times create some distrust towards the case company F which lowers the company reputation and image. However, E2 could not mention any other company stakeholders that could have some trouble from the long delivery times.

In the final question of the first theme, the interviewees were asked about how major they see the supplier's actions for the total supply chain performance. For this E1 responded that the overall supply chain performance is extremely dependent of the supplier's actions. E1 emphasized that if the supply chain is completely dependent of the supplier's actions, for example if one part of the product is only available in one supplier then the supplier's actions are seen highly important for the company F. In this particular case, the skid base comes from a single supplier (TuffSkid), so the overall supply chain performance is highly dependent on the supplier's actions.

Furthermore, the E2 also responded that the supplier's actions are extremely important (5) for the total supply chain performance (1 = not significant, 3 = moderate, 5 = high impact). E2 mentioned that the supplier provides company F with for example order confirmations, deliveries, shipping lists etc. which help company F to track and trace orders and provide reliable information about the changing delivery conditions. E2 also emphasized that it is really important to find a suitable supplier for the company and that the quality is what the company is expecting, so that there would be minimal amount of complaints and returns for the parts and other components that company F purchases from the suppliers.

3.4.2 Future state of supply chain processes

After going through the first theme of the interviews, we are now going to present the results of the second part of the interview. The following part will cover different questions about the future state of the supply chain processes for the case product.

In the first question, the interviewees were asked, what factors or processes they would change in order to improve the supply chain performance for the product. For this, E1 responded that especially if the sales volumes are increasing, company F could have couple products in the stock, because these are not too expensive products and thus there could be for example few basic models in the stock so that it would enhance sales force. E1 also believes that for these kind of products (pumps) there probably won't be instantaneous need, and for these products "here and now" delivery time won't be relevant, but it can be seen as competitive advantage if the company would have the product available in the stock and ready for delivery. E1 also mentioned that it would be preferable for the company F to find a supplier for the skid base who would provide only the skids, which would give more freedom to company F and enable the company to purchase some of the products to shelf. E1 also covered that as far he knows, TuffSkid doesn't want to sell these skids only, and prefer to sell the "complete" package instead.

For the same question, E2 also responded that he would also prefer to utilize some intermediate inventory to increase the delivery speed for the case product. E2 also emphasized that by changing the product structure to be as modular as possible, and also by developing the product so that the manufacturing and fabrication lead times would be as short as possible. In addition, E2 also suggest that if possible, the skid should be equipped (with standard parts and components) in advance, so that when the order request takes place the skid is prepared and for example only the pump could be installed to the product before the shipping. Furthermore, according to E2 the same kind of model could be used with this product, like the company is currently doing with the bigger pump segments, where only the right pipe will come (after the order) and will be installed to the product before the delivery for customer.

Following this, the interviewees were asked about are the supply chain "bottlenecks" easily removed from the system and if so how would they approach these issues. For this question, E1 responded that if the main issue in the supply chain is the skid base for the product and the company F desires to have faster delivery for the product, then these products should be kept in the stock, whether in the supplier or in company F premises. Furthermore, E1 also mentioned that other components for the product are relatively easy to purchase and that the product assembly is relatively simple and fast but requires some repetition from the mechanics so that the workers know the process well enough.

E2 in turn, saw that the bottlenecks are not easily solved and require some work from the company. Additionally, E2 believes that the product will need some forecasts for the volumes and more importantly increase sales for the product, so that company F would be more plausible in the eyes of suppliers. E2 claims that if the company is only inquiring few dozen units from the suppliers it does not make any difference for the current situation, thus the company F needs some sales volume for the product in order to increase the negotiation power against suppliers.

In the eighth question the interviewees were asked about how realistic they think that the supply chain lead time can be reduced to 3-4 weeks, and whether this objective can be achieved in a cost-efficient way. To this E1 responded that he believes that this target lead time for the product is achievable but like he mentioned earlier in the discussion, he claimed that sales force for the pump has to be increased, because according to E1 it’s not reasonable to think that company F should purchase low quantity of different parts and components from the suppliers (with probably high purchase price), rather it would be preferable to purchase these components and parts from one or few suppliers who are capable of producing these with higher quality and in regular bases and he said that in this way even the targeted three weeks delivery time can be seen as long time. To the supply chain cost efficiency, E1 responded that he doesn’t really know the current prices what the TuffSkid is charging company F, but he stated that if we are able to operate more efficiently we can introduce these products with a more competitive price.

However, for the same question, E2 responded that he believes the lead time can be decreased but claimed that the targeted 3-4 weeks delivery time is rather fast for the type of product we are now dealing with. He also mentioned, that he does not have any straight answers or solution for the question, but he mentioned that some changes and improvement it will definitely require so that we can achieve our targeted supply chain lead time.

After this we moved to the ninth question. In this question the interviewees were asked what they think, which alternative is better for the company F, to make the product in house or to use external subcontractors and why. To this, E1 responded that if the demand for the product is ongoing and not just a few units a year, in that case it probably would be desirable to make and design the product in house. On the other hand, E1 mentioned that if the demand for the product is relatively low, which causes that the supply chain processes are not consistent and ongoing rather each delivery is made in case-by-case manner so in that case the company should think the other alternative. To the same question, E2 responded that the product design should be kept in house. Furthermore, E2 emphasized that also the assembly phase should be done in house like the company is currently operating. The interviewee E2 also claimed that company F does not have any special capabilities for manufacturing but has expertise in product assembly operations.

Following this, in tenth question the interviewees were asked about; do they think that the global business and supply chain environment create more opportunities than threats for the supply chain performance. To this question, E1 responded that if the sales volumes for the product stay relatively low, then he suggests that the most “critical” component for the product (the skid) should be done centrally. E1 also continued that by having a molding tool for the skid is quite expensive so it won’t be necessary to make those parts in many different locations, rather to centralize the skid production into single location whether it is USA, Canada, Australia or somewhere else and from that location these skids could be transported closer to the final customers. E1 also mentioned that it won’t be necessary to assemble these products in the locations where there won’t be any ongoing sales, because although these pumps are relatively large in size they are fairly light weight, so they can be shipped and transferred without any major problems. In addition, E1 also underlines the importance of the future sales volumes for the product, hence it won’t be necessary to produce these pump systems in the locations where there is no constant demand for the product.

For the same question, E2 responded that he believes that the global environment creates more opportunities than threats for the supply chain performance. E2 also continued that he believes the European markets are relatively small, if compared to US markets. Thus, he sees more opportunities at the global level than if the product would be only offered e.g. to the European markets. Furthermore, E2 also mentioned that by introducing the product into the global markets, the company is able to increase the sales and also leverage the market force for its advantages.

Next the interviewees were asked how they see the future of the Package Pumping Systems product. To this, E1 responded that he believes the product can reinforce the company repertory but does not see the product to be a huge volume product. Additionally, E1 mentioned that if the “tidiness standards or ideals” keep increasing in the future, then there might be a true market gap for such products. Furthermore, E1 stated that these products can provide a compact total package for the customers as the pump come in a complete system, which is engineered to be easy access “plug-and-play” kind of product, and a reliable system, e.g. if a malfunction or failure is detected in the system, the excess fluid would flow directly into the container (skid base) and prevent the surrounding environment from the leaking. Furthermore, according to E1, conditions where there might be some extra desire for tidiness, this product could offer a considerable solution for that. About the industries that could be suitable for the product, E1 mentioned that for example waste water industry, in which the company F is already providing these pumps, could be one suitable segment for the product.

Additionally, E2 saw the future for PPS quite bright, and refers to current USA sales data, which indicates that the sales volumes are increasing. In addition, E2 mentioned that for some food and chemical industries these total packages could offer a considerable solution for the different industrial purposes. E2 also said that these complete systems seem to be relatively easy to use and implement for different industrial functions, where the entire system can be just purchased, installed and used with no puzzle. E2 also proposed, that these type of products, can improve safety and cleanness factors in businesses, because the system won’t allow the pump-system to mess up the factory conditions so easily. As a result, E2 also sees that the PPS is a great new addition for the pump segment.

Finally, the interviewees were asked to give a free word about the previously discussed matter. To this, E1 only wanted to highlight the importance of the skid and its significance to the overall supply chain performance. On the other hand, E2 wanted to emphasize that these type of products, should be designed to be as simple as possible, because those firms that purchase these systems doesn’t want to have any extra functions or parts to the product, other than to have the pump system itself, which can be easily used and maintained in a daily basis for the company purposes.

3.5 FMEA of the current supply chain processes

In the following chapter, we will discuss and present the results of the Failure Mode and Effects Analysis (FMEA) related to the case company’s supply chain processes. The FMEA method is used in the study to provide more information of the current supply chain processes, and above all help in identifying potential problems and risk areas in the current supply chain operations. Furthermore, due to the geographical distance and tight schedules, the FMEA template was send for two company employees, and because of the current supply chain operations locate in USA, the knowledge and information from the local employee would give also valuable information for the research. Thus, one respondent was selected from the company F's USA unit (R1 = respondent 1) and the other one from the Finnish unit (R2 = respondent 2). The FMEA model was established from the same process steps that were used in the value stream map (marked with green in the figure 23). These same consecutive process steps are also presented in the figure 26 below.

Figure 26. Process steps used in the FMEA survey

The figure 27 below illustrates finished FMEA table filled by the R1. The other one is attached to the appendix 3 (filled by the R2). For each one of the supply chain process steps (order management, engineering, approval, fabrication prep. & procurement and delivery) the two respondents had filled; the potential failure modes in these steps, potential failure effects, failure causes, current process controls and recommended actions to prevent these failures from happening.

SEV = How severe is effect on the customer?
OCC = How frequent is the cause likely to occur?
DET = How probable is detection of cause?
RPN = Risk priority number in order to rank concerns; calculated as SEV x OCC x DET

Process step	Potential failure mode	Potential failure effects	SEV	Potential causes	OCC	Current process controls	DET	RPN	Actions recommended
What is the step?	In what ways can the step go wrong?	What is the impact on the customer if the failure mode is not prevented or corrected?	10	What causes the step to go wrong? (i.e., How could the failure mode occur?)	10	What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?	10	1000	What are the actions for reducing the occurrence of the cause or for improving its detection? You should provide actions on all high RPNs and on severity ratings of 9 or 10.
Order management	Sales expectations are not able to be met.	Delays to providing the project or providing product that does not work as customer expected.	6	Not filling out full data from the customer at time of quotation in the application sheets. Or changes made after the quotation and not updated to data sheets.	8	Application data sheets can/should be utilized. Revisions should be updated inot the data sheet prior to release to Engineering.	3	144	Training of Sales and Support on proper procedures.
Engineering	Process takes too long.	Delay in submittal to customer.	3	Resource overload. Design complexity.	8	None.	10	240	Standard Packages to cover higher volume of orders. Pre-set submittals.
	More documentation prep required than was quoted (time).	Delay or incomplete submittal.	6	Not understanding the scope of requirements for documentation at time of quotation.	7	Experience and requirement reviews at time of quotation.	7	294	Training. How much can we standardize and prepare documentations for these document packages.
	Not meeting submittal requirements.	Delay or incomplete submittal.	6	Not understanding the scope of requirements for documentation at time of quotation.	7	Experience and requirement reviews at time of quotation.	7	294	Training. How much can we standardize and prepare documentations for these document packages.
	New designs are untested design. Fit and function.	Quoted system may not be feasible and the system will need to be requoted or changes to the offer made.	8	Quoted without pre-design validation.	6	Pre-design validation by Product management or Engineering.	4	192	Expand standardized options. Create Exceptions rules.
Approval	Submittals not in a clear format.	Delay in approval.	4	Templates not developed.	6	Using submittals from previous projects as a guide.	4	96	Application specific standard submittals & create templates.
Fabrication prep & procurement	Assembly Instructions missing steps. Assembly drawings missing items or unclear.	Delay in fabrication and/or prolonged production time.	6	Engineering not fully understanding the instruction needs of fabrication and production to complete the assembly. Not fully incorporating system requirements.	5	Input from production on assembly drawings and instructions.	2	60	Application specific and standard system drawings.
	supplier delay.	longer lead time.	6	Inconsistent vendors. Change of suppliers. Inavailability of materials. Lead time was estimated.	8	None.	10	480	Stock standardized components.
	delay in BOM & Fab drawing creation	delay	6	Resource overload. Design complexity.	8	None.	10	480	Reuse standard drawings.
	Misinterpreting specification of components.	delay	6	Unfamiliarity with components.	8	None.	10	480	Training. Design review. Project Kick-off and close-out meetings.
Delivery	All Delivery Processes not followed.	Delays. Defect product.	10	New product not incorporated into delivery processes.	10	Standard process controls. Not necessarily specific to this product.	5	500	Training and standardization.

Figure 27. FMEA table filled by the R1

As discussed in the theoretical part of the study, the FMEA method can be used to give information of the potential failure modes in the different supply chain process steps. Furthermore, FMEA adduces also potential failure effects, potential causes of the failures, current process controls for the failures and also recommended actions to prevent those failures from happening. In addition, by multiplying the severity rating (SEV how severe is the effect on the customer; 1-10) with probability of occurrence rating (OCC how frequent is the cause likely to occur; 1-10) and ability to detect rating (DET how probable is detection of cause; 1-10) the risk priority number (RPN) is given from the equation (SEV*OCC*DET = RPN). The RPN values can range from 1 to 1000, and the higher the number is, the more attention the process step will require to ensure that the process step won't have any failures. Furthermore, those process steps that have high RPN, would probably need more improvements and changes in the future, and companies should target the improvements to those process steps, over the process steps with lower RPN. In this study, process steps that have RPN bigger than 100, are seen as the most prone to the potential failures in the system. Next, the results of the FMEA are being presented by going through the process steps that are also shown in the figure 26.

Order management

R1:

The first step in the supply chain processes is the order management phase. In this stage, the only potential failure was mentioned to be, that if company F is not able to meet the customers sales expectations. This can cause delays for providing the project or product that does not work as the customer was expecting. Potential causes to this: If not filling out the full data from the customer at time of quotation in the application sheets or some changes has been made after the quotation and not updated to the data sheets. The company F uses the following process controls to prevent this; application data sheets can/should be utilized, and the revisions should be updated into the data sheet prior to release to engineering. The respondent proposed the following development recommendation for the process: More training of the sales and support functions about the proper procedures. This process step got the RPN of 144, so it can be slightly significant (RPN>100) but should not be considered as major.

R2:

Also, the second respondent found only one potential failure mode to the order management process. This potential failure was mentioned to be, if the application information is not properly transmitted to the engineering for the review. According to the respondent 2, This potential failure may lead for acquiring incorrect materials and auxiliaries by engineering because of the incorrect application data. Potential cause to this was named; if not filled out the full data from the customer at the time of quotation. Also, the respondent mentioned that the application data sheet can/should be utilized as a current process control to prevent this failure from occurrence. Furthermore, the step got the highest RPN of 360, which indicates that the process step is ranked highest in the risk scale, and thus the process step can be seen significant for the company. Additionally, the respondent 2 didn't propose any specific recommendations for any of the process steps being examined.

Engineering

R1:

For the next process step (engineering) total of four different potential failures were found. The first potential failure mode in the engineering process is that the process takes too long. This can cause delays in submittal to customers and the discovered causes to this are the resource overload. The company does not have any current process controls for this potential failure. The respondent suggest that case company F should have more standard packages to cover much higher volume of orders and also to use and utilize pre-set submittals. This step got the RPN of 240, which means that the RPN is also higher than 100, so the process is significant and likely needs some further examination in the future.

The second potential failure that could happen in the engineering process was mentioned to be that the process requires more documentation preparation time than was first quoted. This potential failure can impact the customers with delays or incomplete product submittals. This problem is caused by not understanding the scope of requirements for the documentation at time of quotation. The respondent claim that the current process control in the company is experience and requirement reviews at the time of quotation. Furthermore, the respondent suggested that by training more employees and by standardizing and preparing the documentations as much as possible for the document packages. This process got the RPN of 294, which indicates that the process is also significant and needs some further consideration.

The third potential issue that could happen in the engineering step was mentioned to be that if the company is not able to meet the submittal requirements. This can have impact to the customers side by providing delayed or incomplete submittals. This failure can happen if not understanding the scope of requirements for documentation at time of quotation. The responded mentioned that the company has the same current process controls as mentioned in the previous (second) potential failure; experience and requirement reviews at the time of quotation. Additionally, the person who responded to the survey mentioned that by training employees more and by standardizing and preparing documentations for these document packages as much as possible. This process step got the RPN of 294, which is the same as in the previous one. This means also that the process is significant and may need some further consideration to prevent the failure from happening.

The final potential failure detected in the engineering process step was mentioned to be that if the new product designs are untested (fit and function). This failure can impact on the customers, because the quoted system may not be feasible, and the system will need to be requoted or some changes to the offer has to be made. The responded mentioned, that this failure can be the result of if the designs are quoted without the pre-design validation phase. In addition, the responded mentioned that the company F is currently using the pre-design validation by product management or engineering to mitigate the risk. In the future, the respondent would like to expand the standardized options and create exception rules to lower this possible risk. This step got the RPN of 192, so the step is higher than the 100, but definitely not the most significant, but still needs some further inspection and regulation.

R2:

One potential failure mode was detected in the engineering step by the respondent 2. This potential risk was mentioned as if the assembly instructions or drawings are missing steps, or if unclear. The respondent mentioned that this may cause for example delays in fabrication and/or prolonged production times. The respondent mentioned that if the engineering is not fully understanding the instruction needs of fabrication and production to finish the assembly the step might go wrong. In addition, the respondent mentioned that the company F uses input from production on assembly drawings and company instructions as a current process controls to prevent this failure. The engineering step got the RPN of 60, which is quite low and indicates low rate of potential failure mode for the process.

Approval

R1:

The third process step that was being analysed was the approval phase. For this stage, only one potential failure/risk was mentioned in the survey. This risk was mentioned to be if the submittals are not in a clear format. This causes delays in approval for the customers. The respondent mentioned that this failure can happen, because there are no company templates formed for this. According to the respondent, company F is only using the submittals from previous projects as a guide to prevent this failure from happening. The respondent recommend that the company should use more application specific standard submittals and templates to reduce the failure/risk from occurring. This approval step got the RPN of 96, which is lower than the threshold (RPN 100), which means that the approval process is not significant in the risk priority number scale.

R2:

For the approval process, the respondent 2 answered exactly the same way as the first respondent. The potential failure was mentioned to be if the submittals are not in a clear format. This may cause delays and the potential cause for this is if templates are not developed. Furthermore, according to the respondent the company is currently using submittals from previous projects as a guide to prevent this failure. The process got the RPN of 96, which is not significant in the risk scale.

Fabrication preparation & procurement

R1:

After the approval phase comes the fabrication preparation and procurement step. For this step total of four different possible failure modes were detected in the survey. The first one was mentioned to be the following: Assembly instructions are missing steps and assembly drawings are missing items or they are unclear. This can cause delays in the fabrication phase and/or prolonged the production time. The respondent mentioned that this is caused if the engineering is not fully understanding the instruction needs of fabrication and production to complete the assembly. Furthermore, the responded mentioned that this can be also caused if not fully incorporating the system requirements in the step. According to the respondent, company F is currently using inputs from production on assembly drawings and instructions as a current procedure to control the potential failure mode. The RPN of the failure mode is 60 (lowest in the survey) which indicates that the probability for the failure is not considered as significant, even though the respondent recommended that the company should use application specific and standard system drawings in the future to mitigate the failure even more.

The second possible failure mode in the process step (fabrication prep & procurement) was mentioned to be the supplier delay. For the customer this can increase the delivery lead time. The following factors can be considered as the causes for this: Company vendors are inconsistent, changes of suppliers, material availability issues and incorrectly estimated lead times. An interesting fact is that the company F doesn't have any current controls to prevent this from happening. The RPN of this failure mode (supplier delay) is quite high 480, which indicates that the process step and this failure mode should be taken into further consideration in the company and probably some solutions for the cure should be developed. Additionally, the survey indicates that the company should use more stock standardized components to prevent this failure. Also, like shown in the survey (appendix 3), the failure mode has only less than 50% chance of detection, which is quite understandable because of the "failure" is almost completely dependent on the supplier's actions.

Third possible failure mode in the fabrication preparation and procurement step was named to be: “delay in BOM & Fab drawing creation”. This means that if there are some delays in bill of material (BOM; list of materials and parts that are required to manufacture the end product) e.g. some product parts or components are late in the delivery, or for some reasons the company has some difficulties of producing fabrication drawings for the product. The respondent stated in the survey, that this failure mode may create delays for the customers of company F. This was also mentioned to be the only potential effect to customers, if not prevented. The respondent mentioned that this failure is caused by resource overload and design complexity. For this, company F currently does not have any specific controls to prevent this from happening and the respondent suggest that the company should reuse the standard drawings as action to prevent this failure. This failure mode got the RPN of 480, which is the same as in the previous. This high RPN indicates that the company should probably take the process step for more detailed observation and find some solutions to reduce the risk. In addition, the survey (appendix 3) indicate that this failure mode has only less than 50% chance of detection, which is quite low rate and should probably be increased.

The final possible failure mode in the process step to be examined was mentioned to if misinterpreting the specifications of components, e.g. if purchased components without proper understanding of the product specific features and requirements. This is said to cause delays for the end customers. This is caused the fact that if employees responsible of sourcing the components are not familiar with these components. According to the respondent, the company does not have any current operations to control this possible issue but recommends; more training, design reviews, project kick-offs and close-out meetings with the project members. Furthermore, the failure mode got the same RPN as the previous two 480, which again is relatively high and should probably need some more detailed analysis in the company in order to lower the risk.

R2:

For the fabrication preparation and procurement phase only one potential failure mode was detected by the second respondent. This potential failure was mentioned to be; if purchased wrong component, which longer the delivery time because of the new component order. This can be the result if errors have been made in the revision control and the purchaser has not sent the new or correct drawings to the supplier. The company is mentioned to use product data management system as a current process control, which lowers the potential failure risks. The process step got the RPN of 200, which is higher than the critical level (100) but indicates that the risk is definitely not significant for the company.

Delivery

R1:

The last supply chain process step that was being analysed in FMEA was the delivery phase. For this process step only one potential failure mode was found. According to the respondent, the delivery process may go wrong, if not all the process steps were properly followed. This issue may cause delays in the delivery phase and some defects to the final products. According to the respondent, the step can go wrong, if the new product is not incorporated into the delivery process. The respondent also mentioned that the company uses standard process controls to mitigate this but relates that these are probably not specific to this case product. In addition, the respondent mentioned that more training and standardization should be used to lower the risk rate. This delivery process got the highest rank of RPN 500, which means that the company should pay more attention to this delivery step and find new solutions to improve its performance and lower the overall failure risk.

R2:

For the delivery phase, the respondent 2 mentioned that the only significant failure for the process is the late delivery. For these late deliveries, the respondent mentioned that there can be several different reasons but claims that the two most common ones are; the supplier late delivery and the company's own production management. Furthermore, the respondent mentioned that the company has not been able to build a sufficient supply chain that could support the customer expectations and that the production capacity problem has not been able to fix fast enough. In addition, the respondent mentioned that the company is trying to use comprehensive supply chain management and project-supervisors that are able to use alternative resources and “back-up plans” as an extra resource for the possible difficult situations. The process phase got the RPN of 300, which is second highest for the respondent 2, and thus should be considered as a significant process step in the risk scale.

3.6 Empirical findings

The need for the research started from the fact that the supply chain lead time for the case product was too long and the case company wasn’t satisfied with that. The case product was first launched to the markets in 2017 as a new product in the firm’s product portfolio (pump segment). The company data indicate that the average lead time for the case product has been around 62 days (9 weeks) in the previous year (2017), and the company is now targeting to reach the delivery time of 3-4 weeks. This indicates that there is a lot of “waste” in the supply chain systems and much needs to be done in order to reach the targeted delivery time. Some notable details of the supply chain statistics:

- Supply chain lead time (average) = 460,75 hours
- Value adding time = 85 hours (18,4%)
- Non-value adding time = 375,75 hours (81,6%)

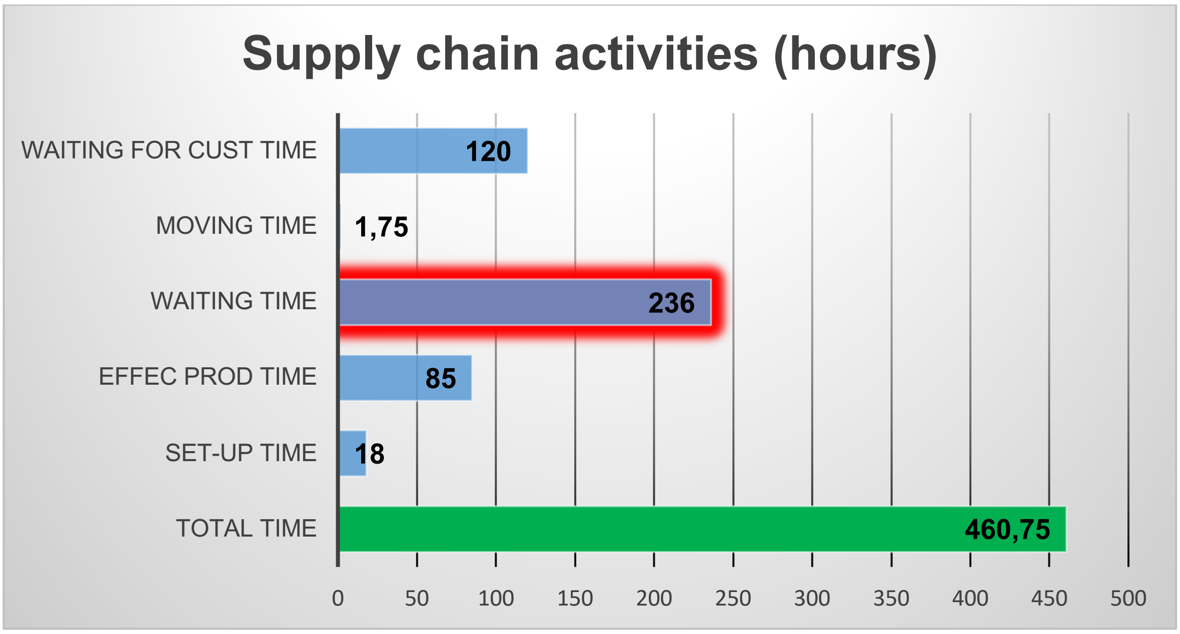


Figure 28. Summary of the activities in the supply chain

Some interesting details from the company statistics; the entire supply chain process contain a lot of waiting-time (236 hours; 51% of total), which indicates that there is definitely room for process improvements in the system. Additionally, the whole process entails also much "waiting for customer time" (120 hours; 26% of total) for which the company F does not have much to influence, because the customer controls the activity and the company F has to only wait for the customer's approval. The remaining supply chain activities (moving time, effective production time & set-up time) do not appear to be particularly time consuming and seem to be quite logical in relation to the company's daily operations. Naturally, some improvements could be directed towards these activities, but in the author's opinion most of the improvements should be directed to the first ones.

Furthermore, the most time-consuming single process in the supply chain was the approval process. The step incorporated total of 128 hours (28% of the total) and 120 hours of it was waiting time. After this, the second most time-consuming process was the engineering step, which incorporated 121 hours (26% of the total) and the third most time-consuming process was the fabrication preparation and procurement process with 116,5 hours (25% of the total). On the other hand, like shown in the figure 23 (chapter 3), company F was having only eight-hour contribution to the approval process, and the rest of it came from the customer side (external effect). Thus, from the company F's point of view, perhaps the two most important/time-consuming supply chain processes are the engineering and fabrication preparation & procurement step (marked in red in the figure 27).

- Approval process = 128 hours (28%) → 120 hours of waiting time
- Engineering process = 121 hours (26%)
- Fabrication prep & procurement process = 116,5 hours (25%)

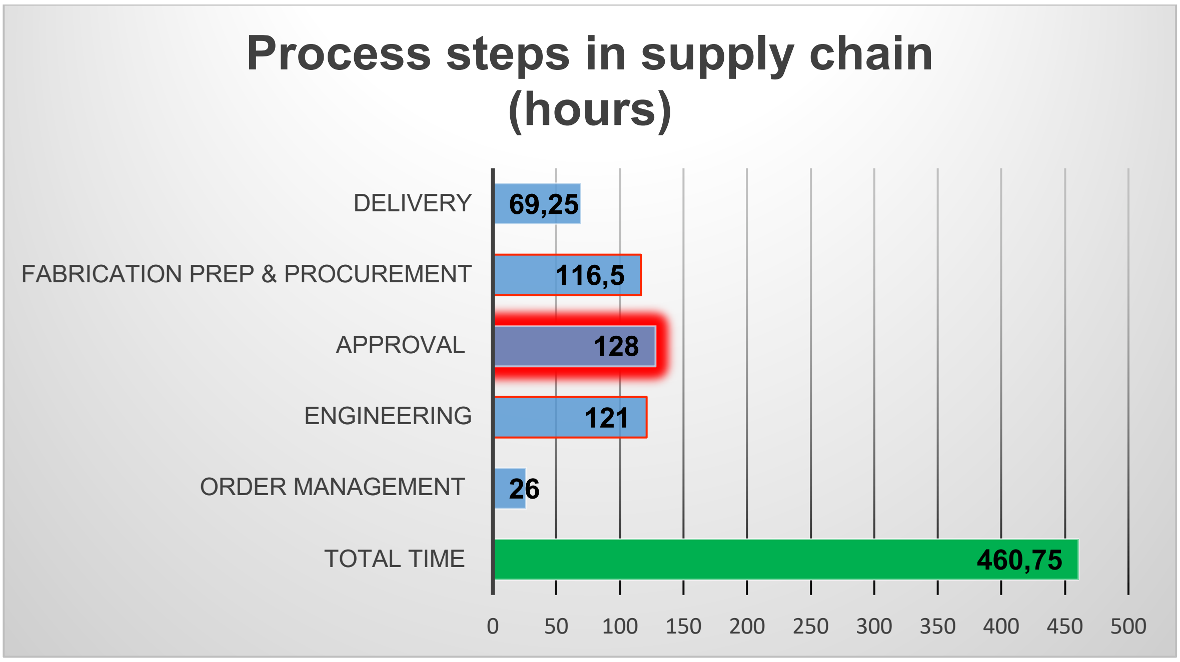


Figure 29. Summary of the process steps in supply chain

As the interviews and observation indicate, the most important part of the case product, especially from the supply chain point of view is the skid (shown in appendix 2). It was also named to be one of the most fundamental parts of the Package Pumping System, and it comes currently from a single supplier TuffSkid (USA). Furthermore, as the skid design and manufacturing are being currently done by a single supplier, it has been mentioned to create negative bargaining power against the company F, and because of this, it can make certain things harder to proceed in a way that the company is aiming for. Thus, the supplier plays central role in the supply chain operations, and more attention needs to be directed to the buyer-supplier relationship and improving the firm's position in the eyes of the supplier.

Furthermore, in general suppliers were seen to play major role in the overall supply chain performance. And because of the strong supplier dependency, company F is having a high impact whatever the supplier is doing/performing. In addition, from the interviews became also apparent that both the global supply chain and business environment was seen to create more opportunities than threats for the company. The interviewees mentioned that the European markets were seen relatively small for the product and that the global markets would give more opportunities and possible sales volume for the product. Hence, the global business environment was shown in positive light for the both interviewees. Additionally, both interviewees mentioned that the product (PPS) is a great new addition for the current product portfolio and it also expands the current product range for the company.

The FMEA survey was formed to find out possible risks and failure modes from the supply chain operations and consequently possible solutions/precautions can be developed to mitigate these risks. The risk priority number (RPN; from 1-1000) used in the FMEA survey tells us how much potential risk is in the supply chain process according to the respondents. Hence, higher the RPN is the more risk is involved in the process etc. From the survey conducted, the following findings became apparent. It turned out that the most “risky” process in the supply chain is the delivery step (RPN; 400). Following this, comes the fabrication preparation & procurement step (RPN; 287,5), order management (RPN; 252), engineering (RPN; 157,5) and finally approval step (RPN; 96). The figure 28 below, summarizes the FMEA results. Moreover, from the survey results became apparent that all of the five process steps handled in the survey were seen to be fairly low-risk in the scale of 1-1000, because the highest (average) RPN was 400 and the lowest 96. So, no RPN close to 1000 were found and all of the processes were marked to have only little or moderate risk in the author’s opinion.

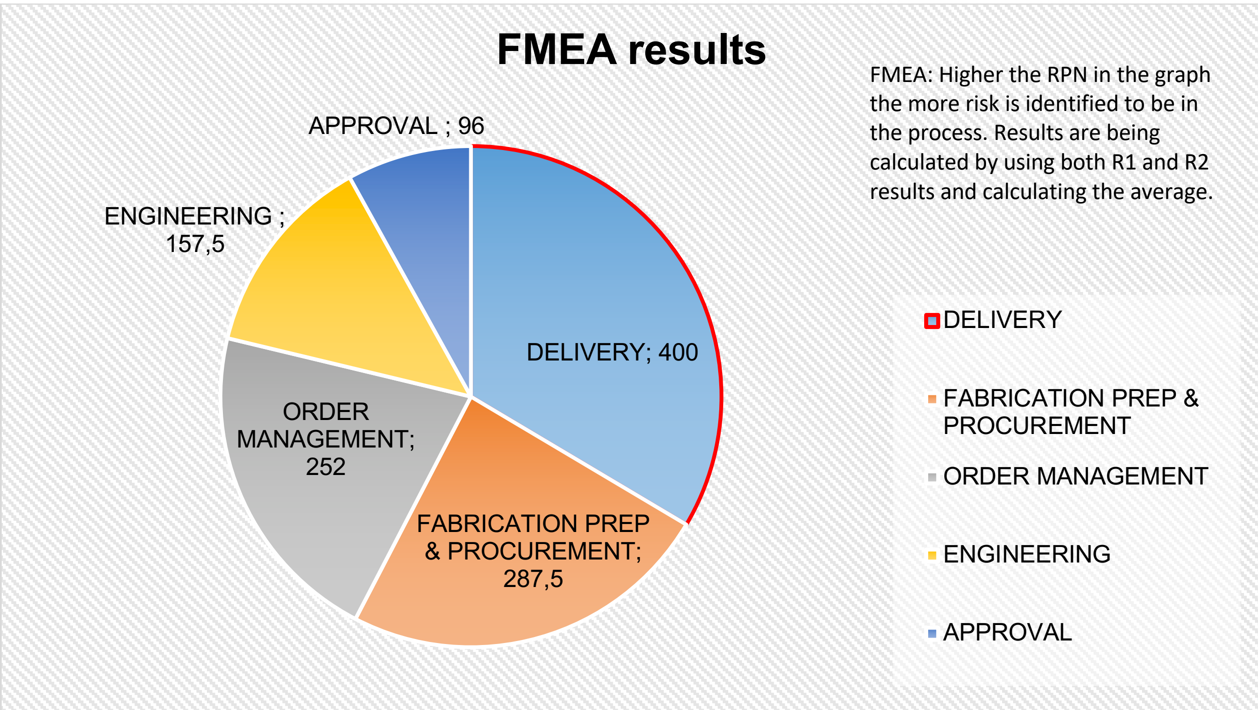


Figure 30. FMEA survey results

As can be seen from the results of the survey, the delivery step was seen to be the highest risky process in the supply chain operations (RPN 400) and the approval phase was seen to be the least risk process in the supply chain (RPN 96). The table 10 below ranks these five different supply chain steps (1-5), from the delivery to approval step, and highlights the potential causes for the failures in these supply chain steps. The ranking is made based on the FMEA results from the R1 and R2 (calculated the average RPN from the results), which tells us that the highest RPN is in the delivery step (RPN 400) and the lowest in the approval step (RPN 96). In addition, the table is filled in according to the survey replies.

1. Delivery	2. Fabrication prep & procurement	3. Order management	4. Engineering	5. Approval
• New product has not incorporated into the delivery processes. • Company F and supplier has not been able to build supply chain which can support customer expextations. i.e. Raw material inventory levels are not set or not at target level.	• Engineering not fully understanding the instruction needs of fabrication and production to complete the assembly. Not fully incorporating system requirements. • Inconsistent vendors, supplier changes, material availability issues, lead time was only estimated. • Resource overload and design complexity. • Unfamiliarity with the components. • New product not incorporated into the delivery processes.	• Not filling out full data from the customer at the time of quotation. • Changes made after the quotation and not being updated.	• Resource overload/ Design complexity. • Not understanding the scope of requirements for documentation at time of quatation. • Quoted without pre-design validation.	• No preformed templates.

Table 10. Potential causes for the failures in the supply chain process steps

3.7 Managerial implications

In the final sub-chapter 3.7 the managerial implications and improvement suggestions based on the empirical research will be introduced. The empirical suggestions have been made based on the information and results of the empirical study. The main findings are collected to the following table under to provide a quick and easy overview of the main perceptions. The left-hand side of the table provides information of the detected issues and main observations and the right-hand side will provide improvement suggestions for the problems encountered.

Managerial Implications	
Issues/Observations Found →	*Suggestions*
1). The skid was seen to be the most important part of the PPS. 2). Long lead time was seen to be the biggest issue in the supply chain operations. 3). An alternative supplier for the skid should be considered. → Faster delivery & lower costs. 4). Suppliers play major role in the supply chain operations. 5). Lots of waiting time & “waste” in the supply chain operations (51% of the total time). 6). The most time-consuming process steps in the supply chain were the approval (28%; 128h), engineering (26%; 121h) and fabrication preparation and procurement (25%; 116,5h). → The process improvements should be directed to these steps. 7). The delivery phase was seen to be the most “high-risk” process in the supply chain (RPN; 400). After that comes the fabrication preparation and procurement (RPN; 287,5) and order management (RPN; 252).	1). Utilize stocks (intermediate stocks) to improve delivery performance. → Better availability and faster delivery. 2). Improve the sales volumes for the PPS. → Greater purchasing power (bigger batch sizes) and higher customer value in the eyes of the supplier, due to the quantities. 3). Decrease the complexity of the product as much as possible → Manufacturing becomes more easy and lower risk for the supplier errors. 4). Product design and fabrication should be made as simply as possible. → Less complexity means better operational performance and more reliability. 5). Utilize more standard processes and components for the product. → Staff training etc. 6). More open communication with the suppliers, customers and internally in the company to enable more accurate information flow and trust among all parties involved in the supply chain. 7). Utilize lean thinking in the company. → Reduces excessive time in the supply chain operations.

	8). Improve the negotiation power against the company suppliers. → Agree on faster deliveries and use sanctions if necessary. 9). Understand the strategical importance of the supplier location. → Better access to the global markets. 10). Standardize and use guidelines for every step along the supply chain. → Less opportunities for errors.

Table 11. Managerial implications of the study

The upper table 11, can be used to identify the main issues in the PPS supply chain and to tackle these bottlenecks/knots to improve the supply chain performance for the case product. In many times, new product launching can create extra pressure to the supply chain system if not well designed. In addition, the product complexity (pump segment) and the type of industry demand form additional challenges for the supply chain operations which cannot often be predicted. From the empirical study, one can safely say that the key is to find a new capable supplier for the skid and from there using a clear step-by-step method to increase the supply chain performance for the product, major cost and time reductions can be achieved.

4 CONCLUSIONS

The main objective in this study was to search ways to increase the global supply chain performance for the case product (Package Pumping Systems). The research was conducted as a qualitative single case study method, where the empirical material was collected by doing semi-structured interviews, FMEA-survey and using the case company materials. In the theoretical part, the study used literature that was mainly related to the supply chain improvement, lean supply chain and delivery performance areas. Furthermore, this academic literature formed a solid background for the basis of the empirical research and it also gave thoughtful information of the previous studies from the relevant academic field. The study was made from the case company perspective and the initial problem in the empirical case was to search out ways to reduce the supply chain lead time for the case product.

In the light of the research, the following conclusions have been made. The biggest issue for the supply chain performance was seen to be the weak performance of the current supplier, that manufactures and deliveries one of the main components for the case product (shown in appendix 2). For this component (skid) the company should probably search for an alternative supplier and negotiate better delivery terms and also lower price, to improve the overall supply chain performance. In addition, the study showed that the supply chain contained a lot of extra time (both waiting time & non-value adding time) which increases the delivery times even more. Thus, there is definitely room for process improvements in the supply chain operations.

Furthermore, the product itself was seen to be rather complex system and hereby the author recommends to design and manufacture the product as simple as possible, which also lowers the possibility for the errors and streamlines the supply chain processes. This also makes the order coordination and processing much easier for the companies that are involved in the supply chain operations. Additionally, the study showed that if planned to launch a new product to the markets, firms must incorporate many different employees and company departments to the supply chain operations and plan processes well in advance to reduce operational problems in the future. Thus, steps for reducing the product and process complexity and standardizing and optimizing processes can have huge impact to the operational performance for many companies in several different industries. (George, 2003)

These empirical findings are also well in line with the previous research. For example, like in the study conducted by the Arbulu et al. (2003), majority (96%) of the supply chain time can be considered as non-value adding time, which was also one of the main observations in this study. Furthermore, based on the study made by Treville et al. (2004) the findings suggest that companies with long supply chain lead time should integrate their planning and forecasting systems with their customers. This means that more emphasis should be put on the system integration and information communication between the companies in the same supply chain system. This links also to the empirical study here, because one of the company's issue was seen to be the lack of communication among the various company departments and suppliers. This increases the risk for errors and even some small changes for the orders can have critical consequences (complaints and new deliveries) if not communicated in the system.

4.1 Answers to the research questions

The main research question in the study was: *"How the global supply chain performance can be improved for the case product?".* To give an answer for the main question, the company should first exploit the lean thinking in the company, so that the continuous improvement and the right mindset can be rooted inside the company. After that, by searching an alternative supplier for the skid the company could have better delivery terms and agreement for the company advantages. Furthermore, the case company should use stocks to increase the product availability which also shortens the lead times. Furthermore, open communication with all the actors in the supply chain can increase the transparency and lower the possible errors in the system which are also linked to the supply chain performance. In addition, the case product was also seen to be rather complex and highly customizable, so the author also recommends to find out ways to make the pump less complex and reduce possible models so that the supplier doesn't have too many alternative ways of making the skid (e.g. many different sizes), because this product complexity can create extra pressure to the supplier side and extend the delivery times, because of the potential capacity issues and lack of resources.

The first sub-question of the research was: *"What is the current level of the supply chain operations in the case company?".* The long supply chain lead time was seen to be one of the biggest issues in the operational performance. On average the lead time was recorded to be about 62 days (9 weeks; 470,75 hours). The aim was to cut down the lead time to 3-4 weeks, so major improvements needs to be down in order to reach the target delivery time. In addition, the supply chain included only 18% value adding time and the rest was seen to be non-value adding time (82%), and one interesting feature was seen to be that about 50% of the total time was waiting time. Thus, the current level of the supply chain operations in the case company can be mentioned to be in the early stages, where the aim is to continuously improve the supply chain processes and find out ways to reduce delivery times and costs.

The second sub-question in the study was: *"What factors affect to the supply chain lead time?".* First of all, like mentioned in the empirical study the supplier was seen to be one of the main attributes to the supply chain performance. By changing the current supplier for more capable the company could save more time and improve the operational performance, which improves the lead time. Furthermore, one key aspect is the material/component availability. The more easily and faster these materials and components are available, the more reliability is the supply chain and lead time more efficient. Communication is also one key aspect of the supply chain performance. Cachon and Fisher (2000) mention that the information sharing is especially important in the situations where the demand is not easily predicted. This fits to the study made here, because the demand for these pumps is hard to predict, and also when launching new product to the market forecasting becomes even more challenging. Additionally, external risks affect to the lead time if not controlled. These can be e.g. country risk, natural disasters and terrorism. Also, by reducing the "extra" waiting time from the supply chain processes and having clear guidelines of how each order process should be handled, can have a positive impact to the supply chain lead times, which ultimately increases the customer satisfaction level. Thus, process standardization and becoming more "lean" can help firms to shorten the order life cycle and become more agile.

Finally, the last sub-question in the study was: *"How the lean methodology can impact to the supply chain performance?".* Like discussed in the second main chapter, the lean originates from Japan, and it was first introduced to reduce waste from the processes. Today the lean method has grown into a broader concept, and many different companies are utilizing the philosophy for their advantages. As the study showed, most of the operational time is considered as waste or non-value adding time, which means that there is lots of room for process improvements. This excessive time can be removed by going lean and continuously improving the operations in the company. This may lead to reduced operational times i.e. lead time reductions and lower costs. Furthermore, the author sees that the lean is not just a management tool, but it is more like a company-wide philosophy that connects all of the actors in the firm.

4.2 Limitations and future research opportunities

The research was conducted as a qualitative single case study method and the empirical material was provided by the Finnish manufacturing company F. There are also some notable limitations that should be considered. The single case study creates some restrictions to the generalisability of the results and the reader should critically reflect the findings also to other products, industries and situations that could have the same kind of issues. Furthermore, the study was made from the SME's perspective so the starting point for the research could be different if viewed from smaller or bigger company perspective. Moreover, the study handles only one product (Package Pumping Systems), which can also limit the generalisability of the results, because of the special features the product can incorporate over other products.

Also, the sample size was quite small, only two semi-structured interviews were made and only two company personnel responded to the FMEA survey. Thus, more reliability for the results of the research could have been obtained if the material and the number of respondents would have been comprehensive. But as usually in the single case studies, in the research the aims to understand the phenomenon in question more profoundly (Metsämuuronen, 2011, 95). Thus, like in this thesis, the material can be much limited in number, but the focus is to understand the phenomenon more deeply. Hereafter, the author recommends that in the future studies researchers should utilize more information from different departments to get more wider view of the phenomenon in question, which in this case, to have data from different employees from different departments (that work in the supply chain) in the case company, to get the best possible picture of the situation. Finally, the author recommends unlike in this study, to get access to the supply chain physically. Meaning that the researcher should be able to spend time in the supply chain operations and follow the process from the investigator's prospect and in that way get more perspective to the supply chain operations and understand every detail in the process more closely.

There can be found several potential future research topics about the topic in question. First of all, it would be interesting to see what kind of impact it would make if the research would have been carried out as a quantitative study and to have many other companies in the analysis. In addition, it would be also interesting to see if the industry or company profile would make any difference to the research findings. Additionally, like in this study, the case situation was based on the new product launching, and the case product itself was highly customized for the different customer preferences, so it would be also interesting to see would the results be different if the case product would be for example commodity product and the product life-cycle at different stage e.g. maturity phase. Finally, it would also be interesting to see how contemporary topics like robotics, RFDI, IoT or blockchain are affecting to the supply chain performance and how firms could utilize these technologies for their advantages in the future.

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APPENDIX 1: Semi-structured interview

The interviewee's name:
Position in the company:
Date:

Current level of supply chain processes:

1) How would you describe the current state of the supply chain processes for the Package Pumping Systems product?

2) What factors do you see, have the most influence for the long lead time for the product?

3) Are these factors also generalized for the other products that the company F is manufacturing? – Why?

4) What are the main issues these long lead times are causing?
   - Company F?
   - Customers?
   - Other company stakeholders?

5) How major do you see the supplier's actions for the total supply chain performance? (1= not significant, 3 = moderate, 5 = high impact)

Future state of the supply chain processes:

6) What factors/processes would you change in order to improve the supply chain performance for the product? – Why?

7) Are the supply chain bottlenecks easily removed from the system? – If so, how would you approach these issues?

8) How realistic do you think that the supply chain lead time can be squeezed to 3 to 4 weeks? – And is this target possible to achieve in a cost-efficient way?

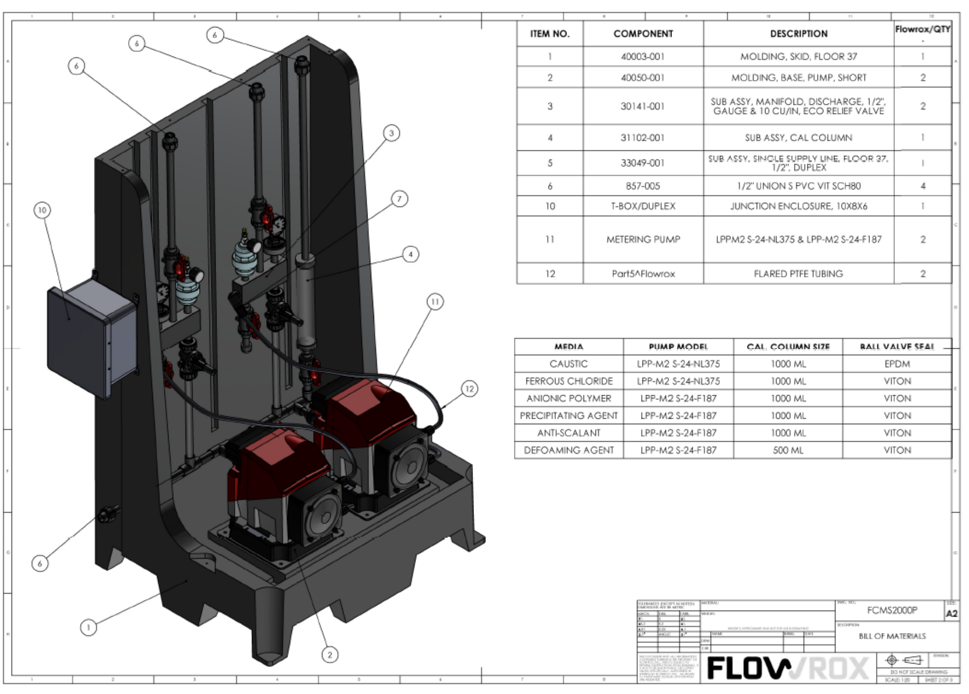
9) What do you think, which one is better for the company, to make the product in house or to use external subcontractors? – Why?

10) Do you think that the global business and supply chain environment create more opportunities than threats for the supply chain performance? – Why?

11) How do you see the future of the Package Pumping Systems product?

12) Free word?

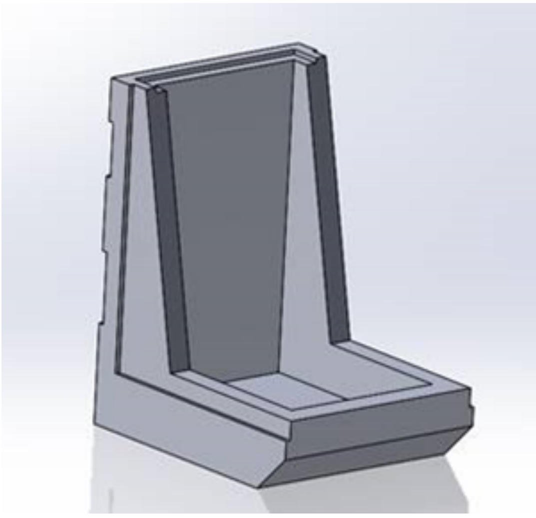
APPENDIX 2: General structure of the Package Pumping System



ITEM NO.	COMPONENT	DESCRIPTION	Flowrox/QTY
1	40003-001	MOLDING, SKID, FLOOR 37	1
2	40050-001	MOLDING, BASE, PUMP, SHORT	2
3	30141-001	SUB ASSY, MANIFOLD, DISCHARGE, 1/2", GAUGE & 10 CU/IN, ECO RELIEF VALVE	2
4	31102-001	SUB ASSY, CAL COLUMN	1
5	33049-001	SUB ASSY, SINGLE SUPPLY LINE, FLOOR 37, 1/2", DUPLEX	1
6	857-005	1/2" UNION S PVC VIT SCH80	4
10	T-BOX/DUPLEX	JUNCTION ENCLOSURE, 10X8X6	1
11	METERING PUMP	LPPM2 S-24-NL375 & LPP-M2 S-24-F187	2
12	Part5^Flowrox	FLARED PTFE TUBING	2

MEDIA	PUMP MODEL	CAL. COLUMN SIZE	BALL VALVE SEAL
CAUSTIC	LPP-M2 S-24-NL375	1000 ML	EPDM
FERROUS CHLORIDE	LPP-M2 S-24-NL375	1000 ML	VITON
ANIONIC POLYMER	LPP-M2 S-24-F187	1000 ML	VITON
PRECIPITATING AGENT	LPP-M2 S-24-F187	1000 ML	VITON
ANTI-SCALANT	LPP-M2 S-24-F187	1000 ML	VITON
DEFOAMING AGENT	LPP-M2 S-24-F187	500 ML	VITON

Structure of the Skid



APPENDIX 3: FMEA of the supply chain

RESPONDENT: (R2)

SEV = How severe is effect on the customer?
OCC = How frequent is the cause likely to occur?
DET = How probable is detection of cause?
RPN = Risk priority number in order to rank concerns; calculated as SEV x OCC x DET

Process step	Potential failure mode	Potential failure effects	SEV	Potential causes	OCC	Current process controls	DET	RPN	Actions recommended
What is the step?	In what ways can the step go wrong?	What is the impact on the customer if the failure mode is not prevented or corrected?	10	What causes the step to go wrong? (i.e., How could the failure mode occur?)	10	What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?	10	1000	What are the actions for reducing the occurrence of the cause or for improving its detection? You should provide actions on all high RPNs and on severity ratings of 9 or 10.
Order management	Application information not properly passed to Engineering for review.	Incorrect materials and auxiliaries may be selected by Engineering based on incorrect application data.	9	Not filling out full data from the customer at time of quotation and not	5	Application data sheets can/should be utilized.	8	360	
Engineering	Assembly Instructions missing steps. Assembly drawings missing items or unclear.	Delay in fabrication and/or prolonged production time.	6	Engineering not fully understanding the instruction needs of fabrication and production to complete the assembly.	5	Input from production on assembly drawings and instructions.	2	60	
Approval	Submittals not in a clear format.	Delay in approval.	4	Templates not developed.	4	Using submittals from previous projects as a guide.	6	96	
Fabrication prep & procurement	Wrong component purchased. i.e. old revision vs new revision	Delivery delay if new component have to order.	5	Errors have been made in the revision control. Purchaser has not sent the new/correct drawings to supplier.	4	Aton system as a item master and revision controlling tool	10	200	
Delivery	Late delivery	There are many possible factors. Two main things which causing late deliveries are supplier on time delivery and own production capacity management	5	Flowrox and supplier has not been able to build supply chain which can suport customer expectation. i.e. Raw-material inventory levels are not set or not at target level. Flowrox production capasity problem has not been able to fix fast enough.	6	Supply chain management. Workshop supervisor know the products and have back-up plans and able to use extra recourses.	10	300	
								0	