Improving Responsiveness of Supply Chain for a Customized Product

A Case Study at a Swedish Lighting Company

Master's Thesis in the Master's Programme International Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

Globalization has made international sourcing as one of the most interesting issues in many literatures and organizations. Moreover, supply chain area is facing new challenge known as customized production, which forces the companies to manage the rapid change and uncertain demand in order to be competitive in the market. In this thesis, a case study was performed at a lighting company in Gothenburg. The study focuses on one customized mechanical component which has very long lead time and high transportation cost. The purpose of the study is to study the whole supply chain of the component from the Chinese suppliers to the lighting company in Sweden in order to provide recommendations for adaptations that could increase responsiveness of the supply chain. Information provided by the lighting company, the logistics company and the Chinese supplier were used for analysis. The extended value stream map was used to identify the problems in material and information flows of the mechanical component. Transportation costs were calculated and compared for using the sea and rail transportation modes. The analysis has shown that there are many supply chain issues which could be improved along the whole supply chain of the mechanical component. The future state map was created to illustrate adaptations which will shorten the lead time and reduce transportation costs. Short and long term plans for implementing the changes regarding to the future state map are presented in this thesis. In order to increase responsiveness in the material flow, an appropriate level of safety stock in the lighting company, the Chinese supplier and the subcontractor company have been recommended. Furthermore, two material planning provided in this thesis are alternative choice in order to prevent out-of-stock at the lighting company. Effective information sharing and new supply contract conditions between parties involved in the supply chain, have also been suggested for improving responsiveness of the supply chain for mechanical components.

Key words: *international sourcing, customized product, responsive supply chain, extended value stream map, lead time, transportation cost, safety stock, material planning, information sharing, supply contract conditions*

Preface

We would like to thank this master thesis supervisor, Professor Christian Koch at the division of Civil and Environmental Engineering at Chalmers. We also owe special thanks to our supervisor's assistant Sjouke Beemsterboer for his guidance and constructive suggestions. We also appreciate the contribution of Patrik Fager (PhD Student, PhD student at the Division of Supply and Operations Management at Chalmers).

We want to thank everyone at the lighting company who spare their time with us and also provided valuable feedbacks to our work. In particular we would like to thank our supervisor at the lighting company, with great commitment, he shared his knowledge with us, and provided useful ideas which improved the progress and outcomes of this thesis.

We also would like to take this opportunity to extend heartfelt thanks to our teachers and families who wholeheartedly supported us during our studies.

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1 Introduction

Development of international market, transports and technology lead to global sourcing. Many companies have decided to move their production sites or outsource parts and components to low-cost countries. Outsourcing could create profit for companies due to low material and labor cost. Although the global sourcing seems as a good opportunity for the company, at the same time it comes with many challenges including language, cultural differences, time-zone differences, long distance and etc. Long distance has direct effect to long transportation time. In order to reduce the transportation time, companies have to compensate with very high transportation cost such as shipping by air. The issues related to geographical distance needs to be considered by companies in order to find good solutions and balance when choosing global sourcing. (Bowersox, 2010; Simchi-Levi et al. 2008).

Besides the global souring, the nature of products has also been challenging the companies. The characteristics of products continuously change based on the market demand. The standardized and functional products, which are produced in mass production and were popular in past years, have been transforming to innovative and customized products. Customized products have shorter product life cycle, higher product variety, and shorter make-to-order lead time compared to functional and standardized products. Consequently, the supply chain of the customized and standardized products have to be managed differently. Close collaboration of the company with customers and suppliers is very important to deal with the challenges of customized production. (Fisher, 1997; Jonsson, 2008; Skjott-Larsen, 2007).

Mentioned issues attract the authors' interest in global supply chain of customized products. Therefore, in this thesis, the case study is conducted at one lighting company in Gothenburg, which provides customized products for customers and also outsources several components from suppliers around the world.

The main objective of this thesis is to study and analyze the supply chain of one critical component which was chosen by the lighting company. The mechanical component is considered as critical because it is used in several products. Furthermore, the component has complex design, long lead time and is very unique in the market. The study covers transport planning, inventory management, demand management and supply management for the mechanical component. These areas have been studied and analyzed in order to provide recommendations for the suitable solutions to the lighting company, in order to overcome the challenges they are facing today.

A mix of quantitative and qualitative methods have been used for gathering information and also for creating the analysis of this thesis. A value stream map and an information flow map have been created for analyzing the overall picture of material and information flows in the entire supply chain of the mechanical component. The analysis includes transport cost and lead time when using different transportation modes. Suggestions for the maximum inventory level and the safety stock level are provided in the recommendation part. Furthermore, adaptations in demand management, between the lighting company and the customer and supply management between the lighting company and the Chinese supplier are mentioned. The recommendation section aims to improve responsiveness of the supply chain for the customized product. Moreover, this study can help the company to reduce transportation costs and eliminate out of stock risks.

1.1 Background

Result of the globalization, in recent years, many organizations start outsourcing significantly. Simchi-Levi et al. (2008) claim “companies outsource everything from the manufacturing of specific components to the design and assembly of the entire product” (p.124). Main target is directed to low-cost countries which can provide cheaper cost of raw materials, components and labor. However, the global sourcing creates both opportunities and challenges. These low-cost countries are normally located far from the companies, which means transportation become an important part because logistics cost and complexity are increasing. (Bowersox, 2010).

The complexity regarding global sourcing rises uncertainty to the company. These uncertainties come from greater distances, longer lead times and decreased market knowledge. Janm Singh et al. (2013) mention “most manufacturers would agree that lead time can be an effective competitive weapon as customers become less patient and less willing to wait for delivery of what they order” (p.37). In contrast, the greater distance from suppliers tends to create longer lead times. Moreover, it declines ability to track and determine where shipments are located or when shipments will arrive and thus becomes a big challenge for the company to deal with. (Bowersox, 2010).

Companies today have more focus on customer satisfaction rather than competitors in the market (Liker & Meier, 2006). Also, a major shift occurs from mass production with standardized products to customized products (Skjott-Larsen, 2007). Supply chain is managed individually based on different characteristics of products and also variable degree of product information provided by customers. Jonsson & Mattsson (2009) mention about customer order decoupling point which “represents the point in the bill of material at which material planning is not dependent on forecast” (p.20). This point will affect production and detailed planning. (Jonsson & Mattsson, 2009).

To grow and survive in this globalization; high competition, rapidly change in technology, and specific customer requirement, either profit or nonprofit organization cannot stand-alone, there are connections to other organizations. A business’s overall performance is a reflection of the whole supply chain, it doesn’t concern how good individual processes are. (Skjott-Larsen, 2007; Slack, 2006). Jonsson (2008) indicates that “supply chain management encompass the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities" (p.5). It is also important to consider both supply and demand side involved in the process which can include "suppliers, intermediaries, third-party service providers, and customers" (p.5).

At present, the traditional relationships between buyer and supplier is changed from arm's length to cooperation and trust. Firms' collaboration is fundamental belief to maximize the customer satisfaction, reduce overall risk and improve efficiency. Information sharing has become an important factor for improving the collaborations and also supporting joint operations; by sharing sales data and future strategies. (Bowersox, 2010; Jonsson & Mattsson, 2009).

1.2 About the Lighting Company

The company was founded in 2005 in Gothenburg, Sweden as a LED modules provider. It has grown and developed to become an innovative company which designs and produces complete fixtures of customized LED modules and systems. The products include the latest LED technology and also contain some alternative components depending on customer requirements such as driver, optics, mechanics and software. Their primary markets include general, street, technical (hospital) and vehicle lighting. The company produces printed circuit board, mounted circuit board and also make final assembly in house. Many components such as electronic components and lamps have been bought from suppliers from different parts of the world such as; Scandinavia, Europe and Asia.

Since, the sales of the firm increased significantly during 2013, the company expanded their facility area in Gothenburg. In 2014, the company established new production site in China in order to create smoother supply for one big customer and also to develop their supply chain in the region. This production site is joint-venture with their Chinese supplier which they have had long term relationship with. This Chinese supplier is responsible for supply of several components and parts. Furthermore, this supplier has been involved in many product development processes with the lighting company.

1.3 Case Study Description

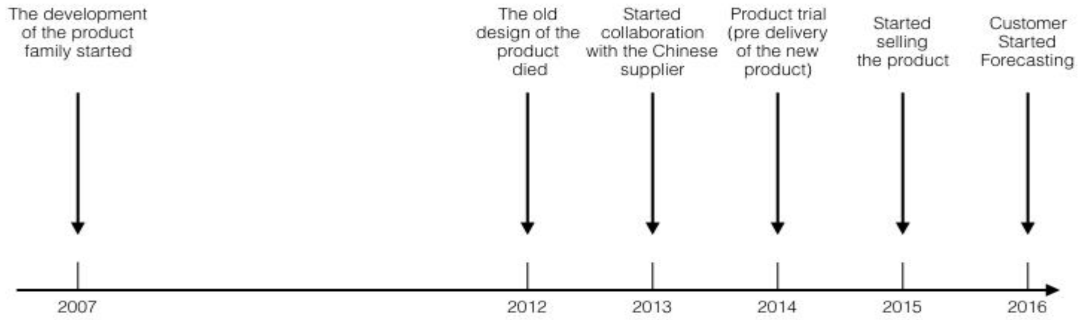


Figure 1 History of sunny product family.

In 2007, the lighting company and their new customer started to develop a unique product family called 'Sunny'. Products included in Sunny product family have high design customization and are used in new market segments for the lighting company. According to some cost and technical issues, the old product design of Sunny was eliminated in 2012 and a new design of the product has been developed since then.

New design of Sunny product family came with several models which have differences in LED, application and price. Many parts and components used for producing the products have been outsourced to suppliers inside and outside of Europe. In 2014, first trial product lot was launched to the market. This product family is very unique in its market and it is also developing continuously. Some models have been eliminated and some new designs have been developed along the years. The customer of Sunny products has not being able to provide demand forecasts to the lighting company since the product has been released to the market. Inability of the customer for providing forecasts is due to unpredictable market demands for customized products.

In 2015, the lighting company started selling the product without any forecasts from the customer; this issues enabled the company to provide forecasts to their suppliers. Result of make-to-order production and non-forecasting, has increased the lead time (as shown in figure 2) of many components. In order to reduce the lead time and also avoid late delivery to the customer, the firm had to rely on some emergency solutions and ship components by plane from China to Sweden; which in its term withdraw a huge transportation cost for the lighting company.

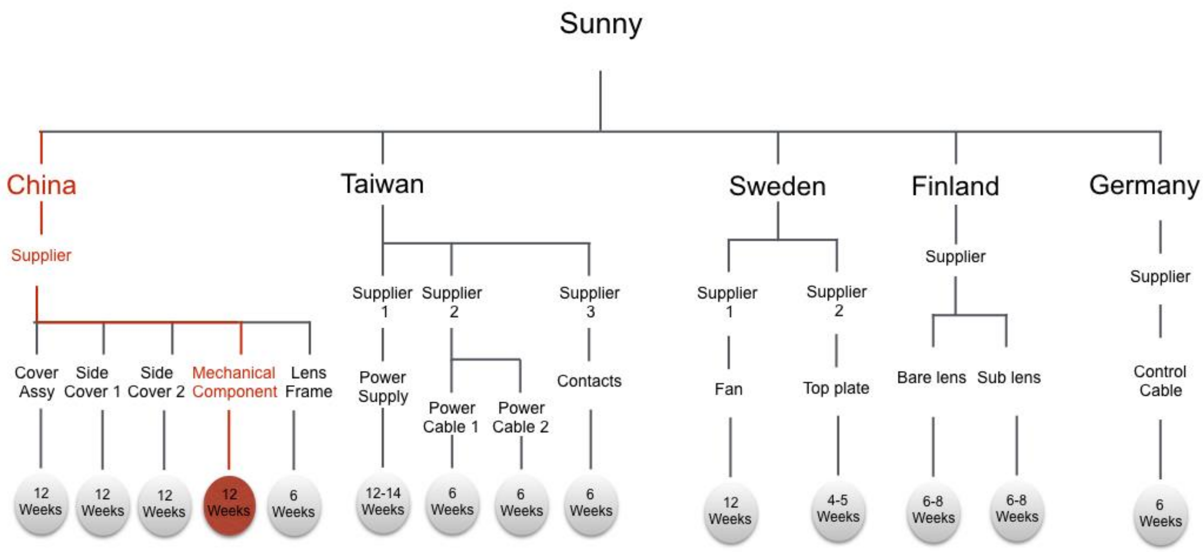


Figure 2 Supplier tree for critical components of sunny product family.

These issues have been significant for one mechanical component which is very heavy in compared to the other parts and it is also used in all the Sunny product models. This mechanical part is made of aluminum by a Chinese supplier in Qingdao. The supplier buy rough tapped aluminum from another sub-contractor. The lighting company started collaboration with this supplier since 2013, and decided to create a joint-venture for the company's new production site in China.

Today the variety of the Sunny products has been increased. New models have been developed while the demand has never been certain. Due to cash flow issues, the lighting company decides to avoid keeping work-in-progress stocks and finished goods inventory. The stocks of the lighting company include components and raw materials; some parts of the company's inventory are owned by Sunny product's customer where they keep the finished goods inventory.

1.4 Purpose and Research Questions

The main purpose of this thesis is to study the whole supply chain of one mechanical component from a Chinese supplier to the lighting company in Sweden in order to provide recommendations for adaptations in transportation mode, inventory management, demand management and supply management. To deliver the appropriate recommendations, information and material flow processes of the mechanical component will be studied and investigated at the lighting company.

Regarding to describe purpose; one main research question has been formulated, which covers a broad picture of the study. The main question that will be discussed and answered through this thesis, helps to find out what factors are affecting the responsiveness of supply chains for a customized product.

RQ: How to make the supply chain of a customized product more responsive?

Moreover, it has been mentioned in the purpose, that this study will cover other aspects such as inventory level, collaborations between different parties and relationship management. Therefore, three sub questions have been formulated and addressed to these aspects in order to conduct a deeper study about respective factor.

- How do different transportation modes affect the cost and lead time of material flow?
- What inventory level is appropriate to have sufficient goods for demand fluctuations?
- How to reduce bullwhip effect by improving collaborations between different parties in the supply chain?

2 Methodology

Following sections briefly describe the design of this thesis. Furthermore, the sections will include the methods that have been taken advantage of in order to select the sample, and perform study in a conscious and rigorous way.

2.1 Philosophy and Design

The theoretical part of this thesis has been framed in order to help understanding the concepts and previous researches related to the case study. The theoretical framework has been created by reviewing literatures, articles and previous researches regarding to the research questions. The aim of the reviews were to achieve crucial knowledge about the factors affecting the responsiveness of the supply chain for customized products.

Managing global supply chain, supply chain management, customer specific products, engineering to order, make to order, extended value stream map, transport planning, demand management, forecast methods, supply side management and inventory management have been used as the keywords for the literature study.

“Theory cannot be understood without empirical observation and vice versa” (Dubois & Gadde, 2002; p. 555). The case study which structures the empirical part of this thesis; underpins the collection of empirical material and also helps to develop practical results for improving the responsiveness of supply chains.

The analysis part of this thesis aims to mention the problems and gaps in the supply chain of mechanical parts, and also identify the root causes of the problems by including the results of interviews and a cause-and-effect-diagram. According to the invoices received from the logistics company, authors were able to calculate the total costs of transportation. These costs are shown and compared between each transportation mode regarding order quantity and lead time. In the section, VSM is constructed to visualize the material flow and information flow for the mechanical component and helps to identify the gaps in the supply chain; for instance, gaps in supplier relations, inventory management, communications and logistics; which lead to increase lead time for the chosen component. A brainstorming session have been facilitated by authors in order to collect ideas about problems in the value stream map. Provided ideas by the staff at the lighting company are mentioned in the analysis section.

According to Dubois and Gadde (2002) it has been “found that the researcher, by constantly going ‘back and forth’ from one type of research activity to another and between empirical observations and theory, is able to expand his understanding of both theory and empirical phenomena” (p. 555). Results of the going back and forth between theories and findings from the case study help authors to provide recommendations for making the supply chain of mechanical components more responsive. Recommendation section include a FSM, short term and long term implementation plans. In short term and long term plans section, the recommendations are provided in different tables; in order to easily identify to which problem the recommendation is addressed to. The table also shows to which articles the recommendations are referred to. Furthermore calculations for material requirement planning and reorder point which are mentioned in recommendation section are provided in appendix IV.

2.2 Case Selection

One step for answering the research questions was to search out for a case study at a lighting company, which is willing to help in finding interesting results regarding to organization's supply chain.

There were three criteria set for selecting the company; first, the authors were willing to perform a case study at a small to medium size company. This criteria was set regarding to previous experiences of authors in working on case studies in large and international companies. Authors were minded to work on a unique case, and also gain more understanding about processes in small to medium size firms. Second criteria was to find an organization which collaborates with offshore suppliers. Third criteria was to find a company which is open to share information and also supports the progress of the case study.

Some consequences have also been considered for selecting this case. For example in small and medium sized enterprises (SMEs), usually people have more workload and it is more difficult to gather certain information and data. Furthermore SMEs usually face several internal uncertainty. (Henrich, Land and Gaalman, 2002). Authors also considered the consequence of not being able to get in touch with the supplier for gathering information regarding to supplier side.

Selection process was done after a meeting at the lighting company. During the meeting authors provided the proposal and the case, and also gained information about the organization and its supply chain.

2.3 Collection of Empirical Materials

During this master thesis, authors were present at the lighting company at most, four days each week from January 2016 until June 2016; for gathering information. The theoretical framework of this thesis was created by reviewing literatures, articles and previous researches; which support the information gathered at the lighting company and the research questions. The major part of information included in this thesis were collected by conducting interviews, studying the empirical observations (supply costs, customer agreement and order forecasts of the product during recent years), and participating in different meetings. (Dubois & Gadde, 2002). Authors were also able to gather information by having small dialogues with employees during lunch time or during breaks. These small chats often triggered the curiosity of authors for conducting more interviews and achieve deep understanding about different issues related to the supply chain of the mechanical component.

A mixture of qualitative and quantitative methods were used in this thesis. Qualitative approach was taken advantage of, in order to collect and break down gathered information. For instance this method was used for conducting and transcribing interviews and brainstorming session, by evolving them with the theories. Qualitative method was applied for studying the problem from lighting company's perspective. (Bryman & Bell, 2011; Jonker & Pennink, 2008).

Meanwhile quantitative method was applied for gathering and analyzing information regarding to; empirical observations that were gathered during different occasions and also interviews. Applying quantitative method in analyzing the information leads to conclusions which include the perspective of authors. (Bryman & Bell, 2011; Jonker & Pennink, 2008).

2.3.1 Questionnaire Development

Twelve semi-structured interviews were generated for collecting information. The interview guides have been different from each other, and directed to different sections such as; finance, marketing, purchasing, production, strategic planning, management, logistics, logistics service providers and supplier side. Despite differences in directions; some questions maintained similar in different questionnaires. Therefore authors minded to get better understanding about the problem from different perspectives, and/or complete required information.

The questionnaire related to the supplier side have been reviewed and approved by the marketing manager at the lighting company before sending the email.

Number of questions included in question guides variated, and they have been formulated in a way to collect data and information, related to the purpose and the research questions of the study. The questionnaires are in English and are provided in the appendix V of this thesis.

2.3.2 Interviews

“Empirical observations might result in identification of unanticipated yet related issues that may be further explored in interviews or by other means of data collection” (Dubois & Gadde, 2002; p. 555).

Significant part of the empirical information has been gathered by conducting semi structured interviews with members at the case company. Interviews carried out with CEO, COO, production engineer, strategic purchaser, financial manager and marketing manager. Few interviewees were asked for a second interview in order to clarify some misinterpretations.

Four interviews were conducted with people outside of the lighting company. Concerned Chinese supplier and logistics company were interviewed who could affect the supply chain of the mechanical component.

Authors collected information by observing and taking notes during twelve conducted interviews. Then the observations were shared and discussed within the group in order to study the gathered information from different perspectives.

In order to transcribe the information gathered during interviews and analyzing them; authors took advantage of coding tool (Bryman and Bell, 2011). Following steps were applied for implementing the coding tool;

I. The information first were organized in order to follow the main topics in the theory part of this thesis, in order to make following the information more smooth and structured.
II. The information then were imported in analysis tables to enable the implementation of coding.
III. The information were broken down to elements and separated; the parts which were related to the purpose of the study and research questions were coded in the analysis tables.
IV. Coded information then were formulated in form of sentences, and structured the interview analysis of this thesis.

2.3.3 Brainstorming

One brainstorming session was facilitated by authors in order to collect ideas from staff inside the lighting company, regarding to two current state maps. Authors have been inspired by brainstorming method based on Dolcemascolo (2006) for creating an extended future value stream map. The detail regarding to this method and how to categorize the collected ideas are mentioned in the theoretical framework of this thesis.

Before the session, authors informed the CEO of the lighting company about the goals of the brainstorming. One email was send to all concerned staffs (CEO, COO, strategic purchasing manager, marketing manager, and purchaser) one month before the session in order to inform them about the event. The date and time of the brainstorming session was set by the COO of the lighting company after an information meeting with authors. The invitation email was sent by the COO.

Date of the session was set on twenty ninth of April 2016. In total four people attended the brainstorming session, the CEO, COO, financial manager and purchasing. Authors started the session by providing a brief presentation about the master thesis, for instance the purpose and research questions of the thesis and problem identification, transport cost calculations and the two current state maps. Then the staff were given few minutes to ask their questions before moving forward to brainstorming.

Then the two main questions for brainstorming were provided to the staff;

1. What needs to be improved or changed in the current state map?
2. What is good to keep in the current state map?

Authors provided two different colors of post-it papers, one pink and one green in order to make it easier to categorize the ideas. The pink post-its were used for writing the ideas regarding to question number one and the green post-its were used for writing ideas about question number two. Totally twenty four ideas were provided (ten green pot-its and fourteen pink post-its).

The post-its then were collected and categorized by authors (the categorization method is briefly described in the theoretical framework and the picture of different categories are provided in the appendix III of this thesis).

2.3.4 Experience at the Lighting Company

Authors started the thesis work at the company on the last week of January 2016. According to the planning and confirmation of the COO at the company, authors have been present at the company for working on the thesis four days each week during the entire master thesis period. During the first weeks of attendance at the company, authors aimed to understand the processes inside the company and processes related to the supply chain of the mechanical components. Authors tried to achieve a helicopter picture of the processes which could possibly be related to the study topic.

"Observations during meetings and other events beyond the control of the researcher contributed information that would not have appeared otherwise. These observations generated new questions on which further interviews could be based" (Dubois & Gadde, 2002; p. 557). During the first contributions with people at the company many information have been exchanged which helped the authors in creating the questionnaires for the interviews. The company provided very good support for both answering the interview questions and also for providing data regarding to customer orders and transport invoices. People at the company always showed interest to the progress of the report and were open to answer short questions which appeared along the way of the research.

2.3.5 Thesis Diary

Daily experiences and knowledge exchange during the master thesis period, have been documented and formed a master thesis diary. The diary includes the date of conducted interviews and relevant meetings for collecting empirical materials. It also describes the achievements for each day spent on this master thesis from the authors' point of view, and contributes about other occasions during the time, for instance the supervision sessions and daily report improvements when working from home or at Chalmers library. The diary has been helping authors for making the whole process more transparent and also for preparing improvement reports for the supervisors before each supervision session at Chalmers. The improvement reports were sent to supervisors by email few days before each session.

2.4 Ethical Considerations

Several ethical issues have been considered for this study. These critical issues were discussed between authors and people at the lighting company in the start point of the research, in order to clarify future concerns. Following issues have been meditate as crucial ethical issues throughout the study;

- "It is the responsibility of the researcher to assess carefully the possibility of harm to research participants, and, to the extent that it can be, the possibility of harm should be minimized" (Bryman & Bell, 2011; P.128). Concerned people were aware of the purpose of this study; they were also informed "to whom the information would be supplied" (Bryman & Bell, 2011; P.129). Authors tried to avoid stressing the interviewees for answering the questions. Interviewees were free to choose the most suitable date and time which fitted best in their schedules, for taking part in the interviews. Questions asked during the interviews were formulated in a clear way in order to avoid misunderstandings. Interviewees were free to refuse answering the questions which were out of their responsibility and knowledge area; and were honored to request for anonymity in this thesis. All these aspects were considered important in order to prevent harm to participants.

- In order to prevent lack of informed consent; a proposal letter which included the aim of the study, background and research questions was provided to the COO of the lighting company before starting the study. People in the company were informed about the details of the research by the COO, before the start date. In the beginning of each interview; authors provided a short introduction about the case and also about the expected outcomes of this thesis. (Bryman & Bell, 2011).

- "The right to privacy is a tenet that many of us hold dear, and transgressions of that right in the name of research are not regarded as acceptable" (Bryman & Bell, 2011; P.136). To prevent invasion of privacy the authors respected company's and individual's values and privacy. At the very early stages of the study, authors signed the privacy policy letter of the company. Authors acknowledged not sharing the information gathered during the research. Participants were allowed to refuse answering to certain questions which were against the privacy of the company. Authors clearly accepted that; all the information gathered through the study, name of participant, the company and their suppliers and products will be treated anonymous with full confidentiality. Authors decided to mention the product family name as "Sunny" in this thesis.

- For preventing deception; authors reviewed the purpose of the study, the progress of the research, the hindrances and expected outcomes during each meeting with the COO of the company. Authors also tried to be clear about the aim the case study to avoid proposing the project something other than it is (Bryman & Bell, 2011). All the theories and information included in this thesis also have been referred to their sources.

2.5 Limitations

This case study helps authors to identify the factors which influence the supply chain's responsiveness; from the lighting company's point of view. Not being able to have direct contact with the Chinese supplier of the lighting company and conducting more interviews with different parties, limited authors of finding out about different perspectives regarding to the subject. People at the lighting company also had different perceptions about the performance of the Chinese supplier and the supply chain. Not having a clear picture of the supplier, limited authors of studying the supplier's issues in depth.

Due to uniqueness of the product; there were limited product history regarding to supply costs, number of orders and transportation costs for the components supplied from China. Authors based the study on the history from April 2014 until December 2015. "Studies focused on processes have to come to an end, whereas the processes in the real world continue. This makes the conclusions a function of the time at which the study was conducted" (Dubois & Gadde, 2002; p. 557).

Not storing the quality defects' history for the components supplied from the Chinese supplier also limited authors from including yield in the VSM and the FSM.

2.6 Delimitation

This study has been conducted to identify the factors affecting the responsiveness of supply chain for customized products; in order to reduce the lead time of mechanical component. Supply chain is a very broad and complex subject and this case study can be implemented from different perspectives. This case; studies the issue from the lighting company's perspective. Transportation time and cost from the origin supplier to the lighting company, lead-time for sending orders from China, ordering point, required SS, customer forecasts, supplier and customer contracts and supplier relations have been studied and analyzed in this case; other aspects that have not been mentioned before will be excluded.

The purpose of this research is to identify the gaps and issues in the supply chain of one specific component all the way from Chinese supplier to the lighting company in Sweden. This study will not include the supply issues from the lighting company to the customers. Analysis of this thesis has focused on gathered empirical materials from the interviews and brainstorming session. Based on analyzed information; authors have identified the factors affecting the supply of the selected component, by creating a VSM and a FSM; and detailed short term and long term implementation plans. The analyses include collaboration of Chinese supplier and the lighting company regarding to supply of the selected component; other collaborations between these parties will therefore not be taken into consideration. This thesis only has focused on the relationships between the lighting company and its customer regarding to sales and forecasts of Sunny. Relationships of the lighting company and its customer for product development has been eliminated from this thesis.

3 Theoretical Framework

In order to answer the research questions, it is necessary to understand the concepts, theories and previous researches. The theories provided in following sections underlie the research questions and support analysis and results of this thesis.

3.1 Global Supply Chain

Supply chains are core business processes in companies today, which create broad networks between firms. These networks usually have global scale and include several activities; regarding to flow of information and materials. These activities need to be managed in order to create value for customers. (Skjott-Larsen, 2007; Jonsson, 2008). Skjott-Larsen (2007) mentions, "one objective of supply chain management is to reduce the total costs of product flow by eliminating this redundancy and integrating operations through close coordination. A second objective is to enhance the value of the final product by making the system, as a whole, more responsive to customer preferences" (p. 44).

During recent years, organizations tend to move toward outsourcing; as a result of this trend, virtual organizations have been created. Meanwhile globalization has increased the size of supply chain networks; and suppliers tend to become specialized by having close collaboration with companies in order to design and develop components. (Skjott-Larsen, 2007; Jonsson, 2008; Kok, 1995; Simchi-Levi et al. 2008). There are differences between supply chains for customized products which have been developed by close collaboration with suppliers and customers; and supply chains for functional products. (Skjott-Larsen, 2007; Jonsson, 2008). Skjott-Larsen (2007) indicates, "supply chains for innovative products should be responsive in order to respond to unpredictable demand. On the other hand, functional products require efficient and stable supply chains to maintain high utilization rates of manufacturing" (p.357).

So, what is a responsive supply chain? And how can companies achieve a responsive supply chain? Gunasekarana et al. (2008) mentions responsive supply chain as "a global industrial paradigm for manufacturing in the twenty-first century. In a changing and competitive environment, there is a need to develop in a cost effective solutions to organizations and facilities that are highly flexible and responsive to changing market/customer requirements" (p. 550). Several articles state that organizations need to increase collaboration within supply chain and also create stronger relationship with different parties involved in the chain in order to be able to create value for customers or in other words achieve more responsive supply chain (Doukidis, 2007).

Companies need to consider different factors in order to insure achieving a responsive supply chain; "timely information sharing, shortening the total cycle time, coordinating the workflow at different tiers of the supply chain, good decision support systems, reducing lead times for information and materials flows, integrating information about operations, reducing redundant echelons, and flexible capacity" have been mentioned as key to success for achieving a responsive supply chain (Gunasekarana et al. 2008; p.559).

As result of achieving a responsive supply chain companies can reduce their inventory level, decrease the risks of being out of stock and also increase their ability to deliver on time. Mentioned factors are all known as ‘critical problems’ for supply chains; which can be tackled by increasing the responsiveness. (Doukidis, 2007). Figure 3 shows the differences between responsive and efficient supply chain.

	Physically Efficient Process	**Market-Responsive Process**
Primary purpose	Supply predictable demand efficiently at the lowest possible cost	Respond quickly to un predictable demand in order to minimize stock-outs, forced markdowns, and obsolete inventory
Manufacturing focus	Maintain high average utilization rate	Deploy excess buffer capacity
Inventory strategy	Generate high turns and minimize inventory through the chain	Deploy significant buffer stocks of parts or finished goods
Lead-time focus	Shorten lead time as long as it doesn’t increase cost	Invest aggressively in ways to reduce lead time
Approach to choosing suppliers	Select primarily for cost and quality	Select primarily for speed, flexibility, and quality
Product-design strategy	Maximize performance and minimize cost	Use modular design in order to postpone product differentiation for as long as possible

Figure3 Efficient supply chain versus responsive supply chain (Fisher, 1997).

The development of global supply chains have made fundamental changes in corporation of manufacturing industries. These changes lead organizations to be more customer oriented by achieving fast ordering and delivery services and also by providing customized products. (Skjott-Larsen, 2007; Jonsson, 2008; Kok, 1995; Simchi-Levi et al. 2008).

Electronic transactions also have decisive influence on the development of global supply chain. Direct procurement and distribution, decreases the level of inventories between companies and increases the responsiveness of the supply chains. (Skjott-Larsen, 2007; Jonsson, 2008; Kok, 1995; Simchi-Levi et al. 2008). Managing global supply chain activities “has encouraged the development of new forms of enterprise in information system operations and third party logistics service providers, who perform the entire process of monitoring the order fulfillment and physical movement and distribution to market” (Skjott-Larsen, 2007; p.33).

Desires for increasing customer satisfaction encourage firms to achieve an efficient supply chain. Customer demands have huge influence on shaping the supply chains and also on supply performance decisions. (Skjott-Larsen, 2007; Jonsson, 2008; Kok, 1995; Slack, 2006). There are other objectives which can influence supply performance such as; improving information sharing and collaborations in supply chain, “involving suppliers in new product development” and “sharing safety stocks of critical items with suppliers” (Skjott-Larsen, 2007; p. 359).

3.2 Customer Specific Products

As mentioned, during recent years supply chains have been extended to global scale. Global supply chains include several business processes, which the main objective of managing them is to create value for customers. This objective can be realized by achieving a responsive supply chain. Improving the information sharing between different parties involved in the supply chain, decreasing the lead time in information flow and material flow and increasing flexibility regarding to market changes are all essential factors to consider for achieving a responsive supply chain. Beside the increasing desires of organizations in outsourcing; producing customized products have also become a trend in many production companies. Following sections will take a deep look in structure of customized products which also require high level of responsiveness in supply chain. Different levels of product customization is carried out in different production environment; this will also be briefly described in following sections.

3.2.1 Moving toward Customized Production

Meneses et al. (2012) claims, “companies have the need to adapt to new demand paradigms in global markets and to withstand traditional economy of scale approaches. The competition between companies transcends conventional boundaries and becomes evident the need for innovation and value added products that are produced in small series instead of the usual scale production” (p. 608).

In recent years many manufacturing companies have been moving from producing functional products to produce innovative customer specific products. Customer specific products are more suitable for small companies which do not have the capacity for mass production. Customer demands and expectations have huge influence on the design and manufacturing of this type of products. (Xue et al. 2016; Skjott-Larsen, 2007; Jonsson, 2008; Meneses et al. 2012; Helm & Conrad, 2014). Moving toward customized production can bring several benefits for industries. Beside enabling flexible manufacturing and distribution; producing customer specific products reduces inventory and production costs. (Skjott-Larsen, 2007; Jonsson, 2008; Novshek & Thoman, 2006). Figure 4 shows the comparison between functional and innovative products.

Aspects of Demand	Functional (Predictable Demand)	Innovative (Unpredictable Demand)
Product life cycle	more than 2 years	3 months to 1 year
Contribution margin*	5 % to 20 %	20 % to 60 %
Product variety	low (10 to 20 variants per category	high (often millions of variants)
Average margin of error in the forecast at the time production is committed	10 %	40 % to 100 %
Average stock out rate	1 % to 2 %	10 % to 40 %
Average forced end-of-the-season markdown as percentage of full price	0 %	10 % to 25 %
Lead time required for made-to-order products	6 months to 1 year	1 day to 2 weeks

Figure 4 Comparison between functional and innovative products (Fisher, 1997).

3.2.2 Customer Order Decoupling Point

The customer order decoupling point (CODP) is used to differentiate between different production environments. It distinguishes the products that are depended to forecasts; from products that are totally integrated with customer specifications and requirements. Make to stock (MTS), assemble to order (ATO), make to order (MTO) and engineer to order (ETO) are production categories which are cited by where the CODP lies in product structure. (Willner et al. 2014; Jonsson, 2008).

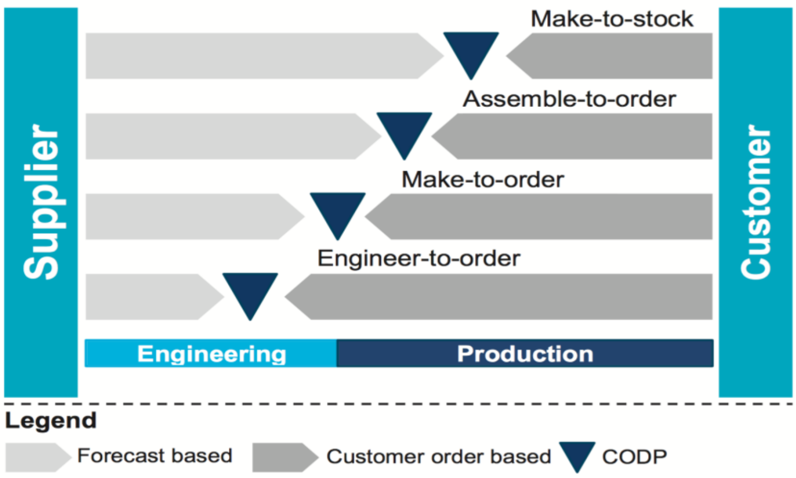


Figure 5 Customer order decoupling point (Willner et al. 2014).

3.2.3 Engineer to Order and Make to Order

Engineer to order (ETO) and make to order (MTO) are two types of production in which the CODP locate far down in their product structure (Jonsson, 2008). Production in these type of companies includes; producing small batches of complex products with long lead time, which are designed according to customer specifications. (Willner et al. 2014; Jonsson, 2008; Mello et al. 2015; Matt, 2014). The stock level of ETO and MTO are usually low; and stocks mainly include raw materials and purchased orders (Jonsson, 2008; Matt, 2014).

However, these two production environments are more similar to each other in compared to MTS and ATO; there are still some differentiations between the value chain of ETO and MTO. Comparison of the value chain in these two environments (Figure. 5) shows that ETO production processes include one extra phase, 'customer specific engineering' which does not exist in the value chain of MTO. The design work of the products and setting customer specifications are finalized in 'customer specific engineering' phase. In MTO case, products are highly customized while customers need to match their desires to pre designed solutions. In this case the design work is completed and the specifications are set before receiving the customer order. Meanwhile, ETO production usually faces high uncertainty regarding to product specification and longer lead time, therefore in this case customers decide upon the specifications and design of the products. The degree of customization may differ in ETO environment, due to the agreements between customers and companies. (Willner et al. 2014; Jonsson, 2008; Mello et al. 2015).

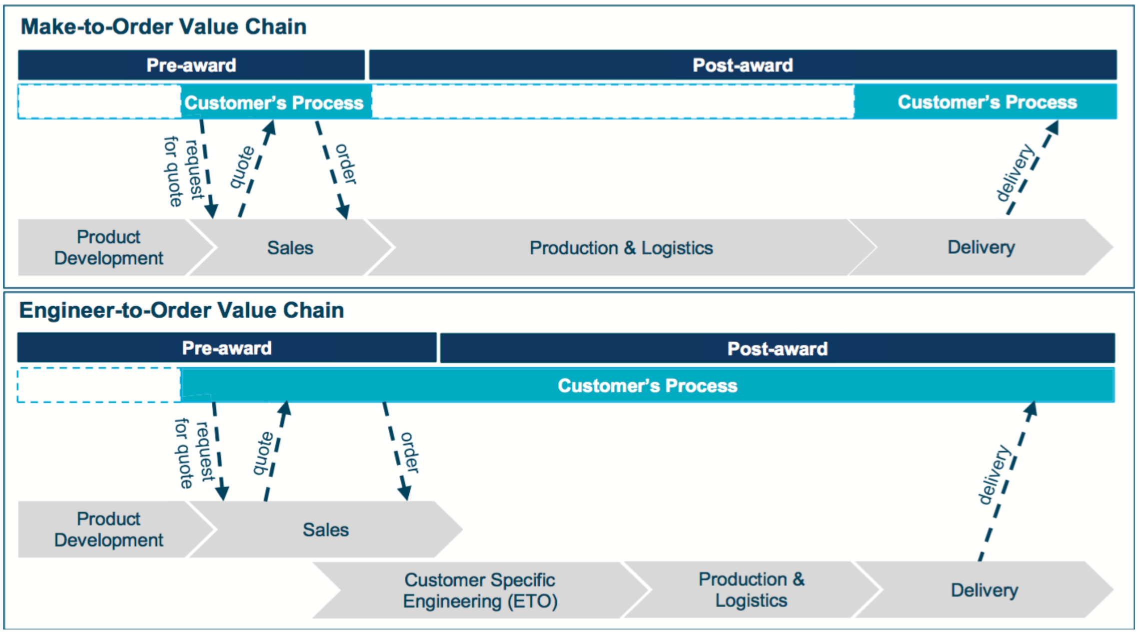


Figure 6 MTO and ETO value chain (Willner et al. 2014).

Mello et al. (2015) states; "in ETO supply chains, the engineering and production activities involve mutual interdependencies that need to be coordinated" (p. 1005). In order to develop new customized products, companies need to interact with stakeholders involved in the supply chain. In these types of production environments, companies need to analyze customer specifications and also consider supplier capacity for implementing desired changes in design and engineering of the products. (Willner et al. 2014; Mello et al. 2015). Close coordination with different parties in ETO supply chain can help companies to reduce the lead time of the products (Mello et al. 2015).

Furthermore delivery plan and production plan of MTO and ETO differ from MTS environment; Jonsson and Mattsson (2008) indicate, “in the case of make-to-order company, whether it is assemble to order, make to order or engineer to order, it is changes in the size of order backlog and thus delivery lead times to customers that constitute the difference between volumes in delivery plans for each period and production plans. Since deliveries are made with delivery lead time, in this case there is a delay between sales plans and delivery plans that must be taken into consideration during planning” (p. 170).

3.3 Transportation

As the result of globalization, outsourcing component from low cost countries has extended supply chain networks. Moreover, ETO and MTO production have increased lead time and the complexity of material flow. “The global supply chain relies on the effective use of transportation networks” (Skjott-Larsen, 2007; p.262). Transportation planning and decisions regarding to transportation mode are included in strategic decisions, especially for companies with ETO and MTO production environment, in order to become more responsive to unique demands of the customers. Following section have focus on this important strategic decision and issues which needs to be considered regarding to transportation of materials.

3.3.1 Transport Planning

Transportation of goods is normally referred to outbound material flow; for instance the flow of material between two facilities which are located in different geographical locations. “Transportation incurs costs” (Jonsson, 2008; p.320). When choosing the transportation patterns, companies must consider synchronization of the flow of raw material (from suppliers to the company) and the flow of finished goods (from the company to customers). (Jonsson, 2008).

Transportation planning also includes planning the required resources for carrying out different transportation activities. The flow of material between offshore suppliers and companies may take place as direct delivery or through different terminals. (Jonsson, 2008). Transport management is included in strategic planning; which includes decisions regarding to distributions via terminals, traffic area and route planning in a political environment. (Jonsson, 2008; Manuj and Mentzer, 2008). “Each transport link is also a unique market, with its own options determined by its own regulations, business practices, and industry characteristics” (Skjott-Larsen, 2007; p.261).

According to Jonsson (2008); “pricing transportation services depends on market forces and the costs incurred by transportation. For transportations repeated at certain time intervals, a freight tariff is normally applied. This is a price list of with fixed rates for different types of transportation" (p.336). He also claims; "transportation distance", "shipped volume", "density of goods", "physical shape of the goods", "High-risk goods" and "supply demand for transportation" as the factors that can affect the price in the tariff (p. 337).

3.3.2 Different Transportation Modes

Considering the suitable transportation mode, is affected by many variables, such as; environmental impacts, lead time, tied up capital, customer service level and inventory level (Jonsson, 2008). "During continuous market competition, focusing on the customer service level, lead times and supply flexibility is very important to analyze the efficiency of logistics processes. Transport processes are a key process that provides physical material flow through the supply chain" (Stajniak & Koliński, 2016; p.37).

Today sea, rail, road and air are the regular transportation modes, used by companies (Jonsson, 2008; Lou et al. 2014). Usually a mixture of different transportation modes are used in one consignment, which is also known as combined transport (also known as multimodal transport). (Jonsson, 2008; Kengpol, 2014). The choice of transportation mode and combined transport have huge influence on total cost of transportation (Kengpol, 2014; Jonsson, 2008; Lou et al. 2014).

Different characteristics of transportation modes, enable companies to choose the most suitable one regarding to their logistics and supply chain strategies. Different characteristics of four traditional transportation modes are mentioned in the table 1 (Jonsson, 2008).

Table 1 Characteristics of traditional transportation modes.

	Rail	Air	Road	Sea
Flexibility	Low	Low	High	Low
Transit time	Long	Short	Short	Long
Owning the right-of-way	Yes	No	No	No
Capability	High	Low	Medium to high	Very high
Accessibility	Low	Low	High	Low
Reliability	Low	Medium	High	Acceptable
Cost	Low	Variable	High	Low

The degree of product customization can also effect on the choice of transportation modes; regarding to this issue, Skjott-Larsen (2007) mentions, “the shift from standardized mass production to small-scale production of customized high-value products involves smaller shipments, a market that favors road and air, over rail and sea transport. Specialized production feeds other production facilities, sometimes located at considerable distances. Distribution has become centralized, relying on fast, flexible transport to substitute for purely localized distribution systems. Realizing the single European Market has included deregulation of transport, removal of customs clearance, and abolishing technical trade barriers” (p.263).

3.3.3 Logistic Service Providers

Based on Świtała & Klosa (2015) statements; “it is difficult to effectively manage the supply chain without an effective cooperation. In this case, an efficient meeting of the demand of the final purchaser becomes the priority”, however “the majority of entities are unable to fulfill this task without the assistance of other businesses, which in practice results in an increased, interest in logistics services” (p.330). Skjott-Larsen (2007) also mention; the transportation market has been changed a lot during recent years and “there has also been a shift from asset-based to skill- and knowledge-based logistics providers” (p.285).
Logistic service providers (LSP) help companies to optimize the transportations, by providing a total transportation pattern; instead of choosing each step separately. Using LSP is the most suitable choice for coordination with offshore suppliers, and also when the shipping batch is small and there is a lack of fixed shipping structures. (Jonsson, 2008).

Świtała & Klosa (2015) mention; taking advantage of LSP makes supply chain more flexible and moreover creating partnership relationship with them, “has a positive impact on the business activities conducted in the supply chain” (p.329).

The relationship of companies with LSP can be carried out regarding to contracts or be informal without considering agreements. It has been proved that the relationship based on agreements and contracts with LSP, has been more profitable for companies. (Świtała and Klosa, 2015). “The contract should cover service requirements, price, payment schedule, duration and other specific exclusions and inclusions. The specific clauses may cover issues related to contract cancellation, price increases and sharing of cost savings. The type of metrics that will be used for measuring service and the frequency of measurement should be included” (Kasilingam, 1998; 238).

3.3.4 Paradoxes in Choosing Transportation Modes

When planning the transportation, it is important to consider the capacity and time restrictions (Jonsson, 2008). Jonsson (2008) claims; “if time restrictions governing the requirement for short delivery times are high, it may be difficult to achieve high load utilization of vehicles" (p.327). Companies tend to have more intention in short delivery time for fulfilling customer demands, than vehicle utilization. (Jonsson, 2008; Skjott-Larsen, 2007).

Customized production requires small and fast shipments; this type of transportation can be more referred to road and air, not rail and sea. However high transportation prices and transportation limitations (regarding to road transport in the case of using offshore suppliers), make companies more interested in rail and sea transportation than air and road. Choosing rail and sea transportation reduces the transportation cost but increases the transportation lead-time. (Jonsson, 2008; Skjott-Larsen, 2007).

Despite the equal value of transportation cost, time and reliability for customers, companies tend to focus more on transportation costs (Lou et al. 2014, Jonsson, 2008; Skjott-Larsen, 2007). As mentioned before many companies use combined transport in order to reduce the costs and time of the transportation (Kengpol, 2014; Jonsson, 2008; Lou et al. 2014); however according to Kengpol (2014), this decision may have influence on the risks of transportation (damages, accidents). "In the case of transportation and logistics processes, accidents and risks not only imply a direct cost, but also reduce the competitiveness of exports" (Kengpol, 2014; p.582).

The intention of companies in reducing logistic costs conflicts with their intention in increasing the customer service level. Achieving high level of customer service level, requires high inventory level and usage of more costly transportation services. (Kasilingam, 1998; Jonsson, 2008; Skjott-Larsen, 2007).
Kasilingam (1998) claims; "inventory and transportation decisions are closely related. A lower inventory level may be maintained if a premium or faster transportation mode is used", "if a slower mode is used then a higher level of inventory may be needed. Hence a trade-off is needed to determine the optimal inventory level" (p. 5). Figure 7 shows the relationship between transportation cost versus inventory cost when using fast and slow transportation methods.

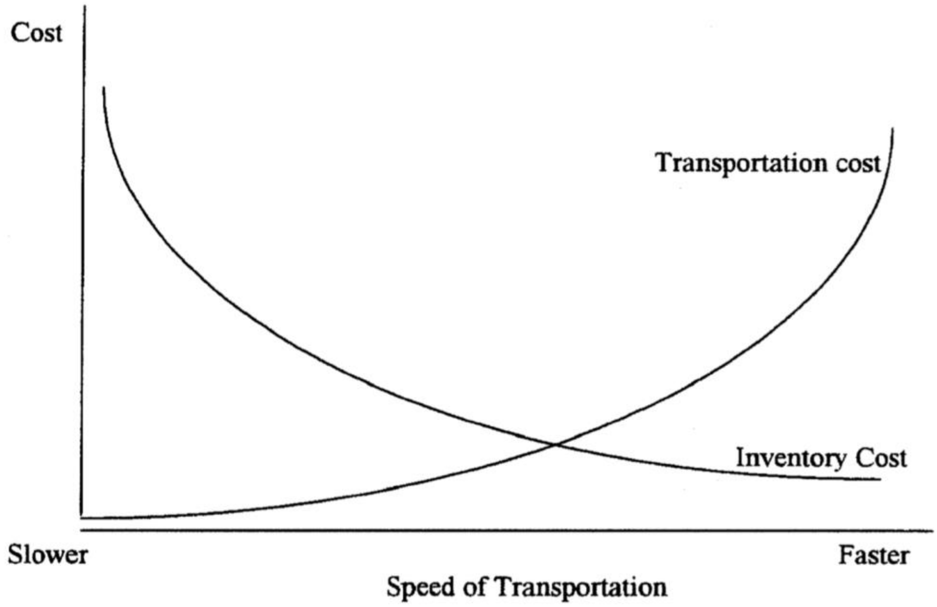


Figure 7 Inventory vs transportation cost (Kasilingam,1998).

3.4 Extended Value Stream Map

Choosing transportation modes for raw materials or any product' components has big influence on total lead time of the product. Long lead time can cause high level of safety stock in the company. In contrast, the company might decide to reduce the lead time by spending more money with faster transportation type. However, these transportation problems can be moderated if the company uses the right tool. In this section, extended value stream mapping and information flow mapping are described as the tools to manage the material and informational flow.

Value-stream mapping (VSM) has been used effectively by many organizations to improve internal processes. According to Matt (2014), ETO products are usually project based. Each unique project in ETO environment consists of new designs, and new customer demands regarding to specifications and shipment date. Application of the traditional value stream mapping is difficult in ETO environment; due to distinctions between customized production and mass production, for instance; lack of product background information and stock level. The VSM and the future state map need to be adapted to this type of product (Matt, 2014).

3.4.1 Extended Value Stream Mapping

"*Value* is that which gives a product worth in the eyes of the customer", "*the value stream* is the set of all the actions required to bring a product to the customer, including information and material flow" and "**the extended value stream** is the value stream of material and information flow from raw materials to the end user; it crosses suppliers, customers, and facilities" (Dolcemascolo, 2006; p.15).

Nowadays, many companies outsource product's parts or components and do only assembly processes in house. A greater benefit will ensue by improving the extended value stream than by only improving the door-to-door (in house) value stream. Dolcemascolo (2006) mentions that main part of a product's total cost comes from supplier processes which are not identified in a typical VSM. Therefore, to reduce overall supply chain cost, an extended value stream mapping of supply chain must be created. (Dolcemascolo, 2006).

3.4.2 Creating the Extended Value Stream Mapping

The extended value stream map consists of two main flows. First is information flow which will be mapped from right to left at the top of the map. While material flow on the bottom of the map will be mapped from left to right. (Dolcemascolo, 2006).

Dolcemascolo (2006) mentions about eight steps to make the extended value stream map:
Step 1. Create the end customer box at the upper-right-hand side of the paper.
Step 2. Create a process box representing your own organization.
Step 3. Create process boxes representing suppliers.
Step 4. Create a box or boxes representing raw material suppliers.
Step 5. Create boxes representing information process of your own organization and your key suppliers.
Step 6. Begin mapping information flow from right to left, start with the customer.
Step 7. Map the information flow from the production control departments of each organization to the process boxes.
Step 8. Calculate and fill in detail of metrics at the bottom of the extended value-stream map

3.4.3 Metric Definitions

To understand the extended value stream mapping, users should know all words' definition which will be included in the map.

According to Dolcemascolo (2006) and Liker (2004), there is time spent for actions that create value and for actions that create no value in the value stream:

- **Value-creating time** is the time for actions that change a product such that value is added; for example, mounting LED on the circuit board to be a part of lamp is value-added action. The costs for these kind of activities are included in the price which customers pay. Therefore, the time spent for mounting activity counts as a value-creating time.

- **Non-value-creating time** does not increase the worth of a product in the eyes of the customer. For example, transporting LED boards to stock and keep in the shelf or warehouse for several weeks before starting assembly to a lamp. Storing and transporting product do not create value in the eyes of the customer but it is considered as an unavoidable non-value-creating time.
- **In-plant time** is the time that materials, components or products are in the factories or plants, and it includes both value-creating time and non-value-creating time.
- **Transport time** is the time that materials, components or products are moving between facilities.
- **Total time** is the total lead time from raw materials to the end user
  Total time = in-plant time + transport time

3.4.4 Detailed Process of Information Flow Mapping

Communication barriers can cause delay and also create many other wastes in processes. The extended value stream map doesn't have enough space to show all the details about queues in the information flow (Dolcemascolo, 2006). Dolcemascolo (2006) recommends that process maps or flowcharts should be constructed separately from the extended value stream map, in order to show the information flow in detail. The detail mapping will show **queue time** and **number of information transfers** which will be analyzed to eliminate or simplify in the future state.

3.4.5 Developing the Future Value Stream Map

Following sections briefly describe the steps for developing the Future Stream Map (FSM).

<u>Brainstorming</u>
According to Dolcemascolo (2006) and Liker (2004), the next step after creating a VSM is to find the potential improvements in the information flow and material flow. These improvement and process development then will be used for developing the FSM. (Dolcemascolo, 2006; Liker, 2004).

In order to gather improvement ideas, a brainstorming session must be facilitated. (Dolcemascolo, 2006). "There are several techniques for brainstorming", "the most effective technique for eliciting the most ideas is the "sticky note" method". (Dolcemascolo, 2006; p.151). Participants in the brainstorming session must be given few minutes to state their ideas about how to improve the current VSM.

After the brainstorming session, the sticky notes will be collected by facilitators, "each idea is given a sequential unique number and is ranked high, medium, or low (indicating the level of difficulty in implementation)" (Dolcemascolo, 2006; p.152):

- **High (H):** Ideas which are hard to implement will be rated as H. These ideas must be included in long term implementation plan.
- **Medium (M):** "The idea can be implemented in a short term with some validation and analysis".
- **Low (L):** These ideas are easy to implement and can be included in short term implementation plan.

<u>Developing Implementation Plans and the Future Stream Map</u>
After ranking the ideas with H, M and L; the long term and short term implementation plan can be developed. The action plans then will be used as base for creating the FSM. (Dolcemascolo, 2006).

3.5 Inventory Management

Managing responsive global supply chain, can be realized by creating synchronization in material flow and information flow. Managing inventories in different sites of a supply chain is one important step for achieving high degree of customer demand responsiveness. Considering inventory level and safety stock regarding to demand variations; are very important factors which can help to decrease the bullwhip effect. Beside transportation management, inventory management is also included in strategic decisions of companies.

Toovey (2000) defines inventory management "as the branch of business management concerned with planning and controlling inventories. The role of Inventory Management is to maintain a desired stock level of specific products or items. The systems that plan and control inventories must be based on the product, the customer, and the process (either manufactured or purchased) that makes the product available. The cost of maintaining inventory throughout the entire process is a hidden cost, but nevertheless becomes part of the product cost" (p. 1).

3.5.1 Inventory Strategies

Jaber (2009) mentions that inventory management needs to be imbedded in company's strategies. He also describes some strategic objectives related to inventory management;

"

- *Increased vertical integration and process orientation cause much stronger relationships between subsequent stages both within companies and with their partners. This leads to, for example, closer connections between inventories in various stages of fabrication: they become more dependent on one another and on the policies of customer service. Depending on at which level of fabrication policy-directed stocks are kept, lead times for meeting customer demand can be made shorter or longer.*
- *The locations of inventories in intercompany supply chains influence the smoothness of relations and can be used for optimizing joint profitability of*

supplier and vendor companies—for example, by utilizing differences in taxation of various countries or some local savings possibilities in shaping a complex distribution system.

- *It is often said that in modern logistics systems, information is traveling instead of materials. However, there are many examples that show that the flexibility and speed of an electronic commerce system can be utilized only if it is supported by high-quality logistics systems, which include appropriately sized and located inventories (the prerequisites of flexible customer service)*" (p. 13).

3.5.2 Inventory Management in Global Supply Chain

Manufacturers which tend to follow the outsourcing trend, are willing to collaborate with offshore suppliers. The reason behind this decision is to reduce the costs. Comparing the purchasing price of components shows remarkable cost savings when using offshore suppliers. In order to ensure that the cost savings will bring profit for manufacturers; companies need to consider the inventory growth which is the outcome of choosing offshore suppliers. Purchasing from offshore suppliers makes it difficult for companies to implement a pull system; therefore manufacturing companies usually intend to purchase big batches (sometimes for one year consumption) and keep the material in stock (Dolcemascolo, 2006; Skjott-Larsen, 2007). It is important to consider and analyze the hidden costs of inventories such as; tied up capital and the costs related to occupying the floor space, when purchasing material from offshore suppliers. (Dolcemascolo, 2006; Jonsson, 2008).

In order to make inventory management more efficient; companies that are using offshore suppliers need to maintain "a very low work-in-progress inventory to minimize excess and obsolete inventory"; on the other hand key suppliers need to keep safety stock in order to become more responsive to customer orders (Skjott-Larsen, 2007; p.360).

3.5.3 Safety Stock

One of the main challenges for managing supply chains is forecasting the supply and customer demands. Consequences of errors in forecasts are overstocks and shortages which both have huge influence on customer satisfaction. Safety stock (SS) is a countermeasure, which supports supply chains performance, when facing forecast errors and demand uncertainties. (Sachs, 2015; Skjott-Larsen, 2007; Jonsson, 2008; Dolcemascolo, 2006; Toomey, 2000; Simchi-Levi et al. 2008). Companies face a paradox regarding to risks and costs when deciding upon the size of the SS, Müller (2011) describes; "perhaps the easiest, but certainly not the least expensive, method of reducing supply chain risks is to have more safety stock. It's a tradeoff. More buffer stock, less risk but at a higher cost—less safety stock, more risk of stockouts but at a much lower cost" (p. 238).

SS can be located in different points within the supply chain; according to Toomey (2000) "if the number of stocking locations can be reduced, the need for safety or buffer stock is also reduced. If the flow of product is directly from the plant to the customer, there will not be any safety stock required other than at the manufacturing facility" (p. 184-185). Meanwhile in order to secure the performance of global supply chains; safety stocks need to be maintained at suppliers plants also (Skjott-Larsen, 2007).

Surplus SS level will increase the tied up capital and inventory costs without creating value for customers. Less demand fluctuations and improvements in forecasting customer orders can help to reduce the level of SS. (Sachs, 2015; Skjott-Larsen, 2007; Jonsson, 2008; Toomey, 2000).

3.5.4 Calculating Maximum Inventory Level and Safety Stock

As mentioned before many supply chain problems can be addressed by considering SS. (Sachs, 2015; Skjott-Larsen, 2007; Jonsson, 2008; Dolcemascolo, 2006; Toomey, 2000; Simchi-Levi et al. 2008). According to Dolcemascolo (2006; p. 107-108); SS can be determined by using simple calculations;

- "*Safety stock* = Safety percentage X (replenishment cycle stock + buffer stock). The safety percentage should be based on supplier reliability, quality, and delivery performance. The safety stock is the amount of extra stock that compensates for delivery or quality issues".

when

- "*Max inventory level* = Replenishment cycle stock + buffer stock + safety stock

where

- *Replenishment cycle stock* = Replenishment cycle (days) X average usage/day. Replenishment cycle stock is based on the average usage over the replenishment cycle".
- *Buffer stock* = Confidence factor standard X deviation of daily usage replenishment cycle (in days). Buffer stock is the amount of extra stock that compensates for variation in daily usage on the factory floor".

3.6 Material Planning

Material planning has direct effect on inventory level and aims to synchronize supply and demand of materials; for instance, "if delivery take place too early, there will be unnecessary capital tied up, and if delivery is too late there may be shortage, with production disruptions and poor delivery service to customers as a result" (Jonsson & Mattsson, 2008; p.208-209).

Another factor which have impact on responsiveness of supply chain, tied up capital and customer service level is material planning. Material planning include understanding about planned orders, order quantity, delivery plans and ordering time plans. Understanding these factors and comparing them with actual stock level, help companies to decide the reorder point (Jonsson & Mattsson, 2008; Jonsson, 2008).

3.6.1 Reorder Point

In order to replenish the stock, when the inventory level is less than 'reference quantity' a reorder point must be calculated (Jonsson & Mattsson, 2008; Jonsson, 2008). As illustrated in figure 8, planning new orders must take place "if the stock balance plus any planned open orders fall below the re-order point"; "thus, in addition to the safety stock, the re-order point presents a forecast for demand during the lead time" (Jonsson & Mattsson, 2008; p.211-212).

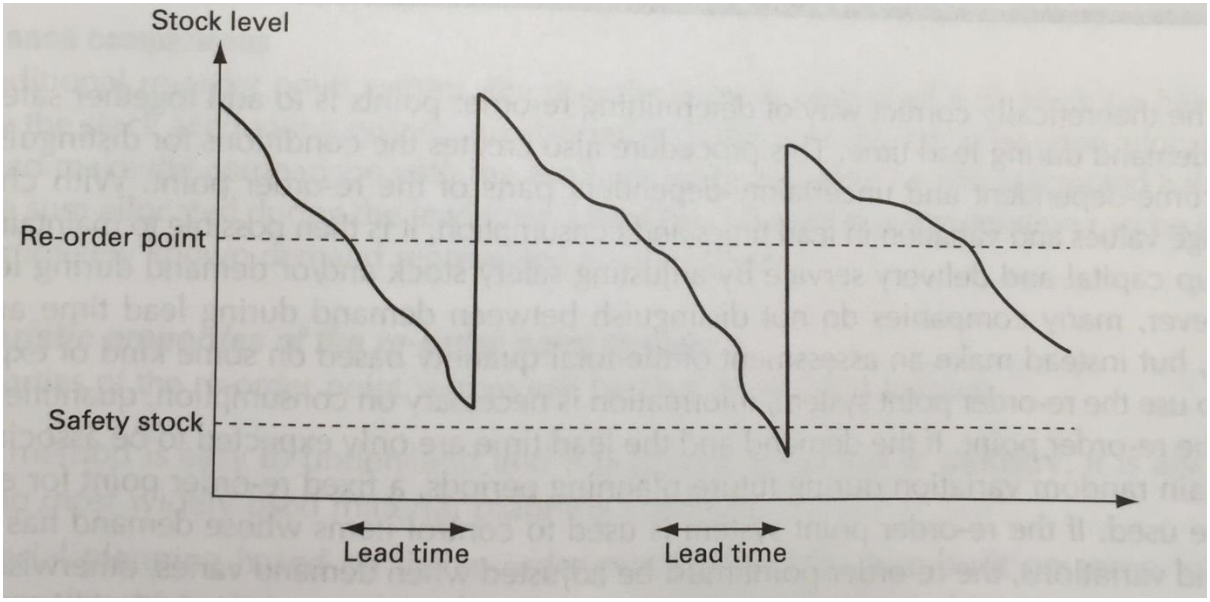


Figure 8 Basic principles of the re-order point system (Jonsson & Mattsson, 2008).

According to Jonsson and Mattsson (2008) reorder point can be calculated by using a simple formula;

$$ROP = SS + D \times L$$

ROP = reorder point
SS = Safety Stocks
D = demand per time unit
L = lead time

3.6.2 Material Requirements Planning

"Material requirement planning (MRP) is a material planning method that is based on point in time for scheduling new deliveries being determined through the calculation of when further requirement of materials arise, i.e. when the calculated stock on hand becomes negative" (Jonsson & Mattsson, 2008; p.219).

MRP can be grouped per day, week, month or other time periods. The shorter planning period is used, when information is more detailed and accurate. While the longer time period is appropriated with information which is based on forecasts. (Jonsson & Mattsson, 2008).

As shown in the table 2, in week 7 stock is -10 which get below 0. Therefore, a new order must be delivered in that week in order to avoid shortage.

Table 2 Illustration of material requirements planning (Jonsson & Mattsson, 2008).

Week	0	1	2	3	4	5	6	7
Forecast/requirement		10	10	10	10	10	10	10
Stock on hand	20	10	40	30	20	10	0	-10
Planned order delivery			40					
Planned order start					40			

3.7 Demand Side Management

Long lead time can cause high level of safety stock in the company. In contrast, the company might decide to reduce the lead time by spending more money on faster transportation mode. However, these inventory and transportation problems can be moderated if the company knows the right way to manage the demand side. Grabara and Starostka-Patyk (2009) mention that demand prediction is a very important tool in order to generate production plans, choose transportation modes, manage the surface or create the service level. The higher the demand uncertainty, the more it is difficult to establish and follow the plan.

3.7.1 The Bullwhip Effect

There are dynamics which exist between firms in a supply chain. The small variation in customer demand creates an increasingly large variation in upstream demand along the supply chain. This phenomenon is known as the bullwhip effect. Gaps in material or information flow, create markable fluctuations in supplier side. The bullwhip effect can cause major problems such as exaggerated inventory investment, high level of safety stock, misguided production plans, wrong transport choice and poor customer service. (Moll, 2013; Slack, 2006).

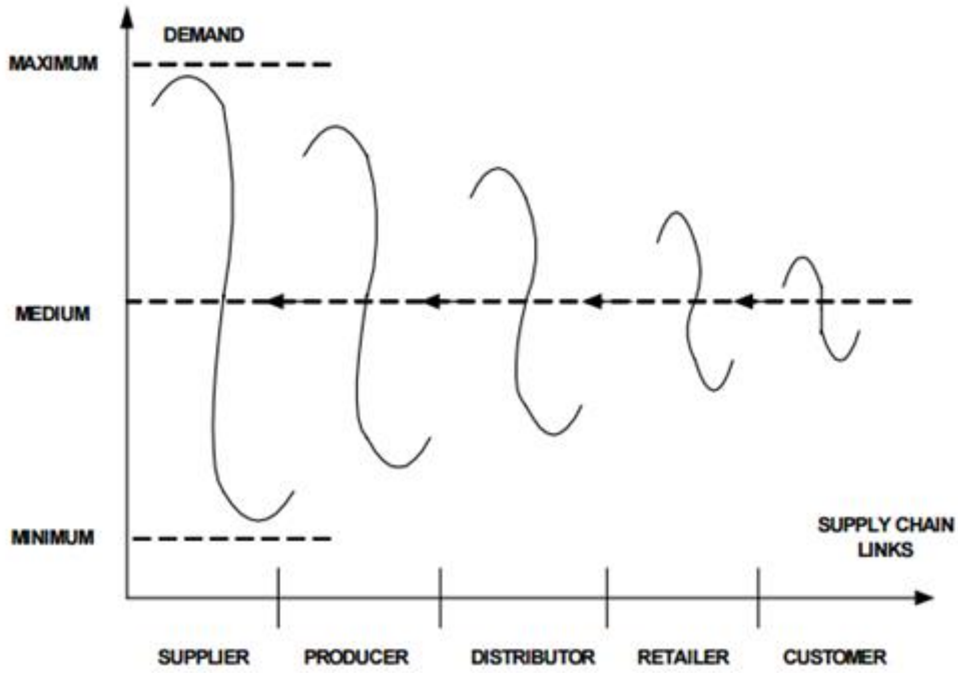


Figure 9 The bullwhip effect in supply chain (Grabara & Starostka-Patyk, 2009).

3.7.2 Causes of the Bullwhip Effect

There are many factors which cause the bullwhip effect such as; *sales promotion*, like price discounts, quantity discounts and coupons; which increase the sale volume in the short time and then customers stop buying until the products have been consumed. (Jonsson & Mattsson, 2009; Skjott-Larsen, 2007)

*Absence of plan alignment between parties involved***,** is another cause for the bullwhip effect. Any re-planning of the company can create instability and changes in demand. Therefore, it is significant to communicate frequently between supplier and customer about change in plans, material movements, stock levels and other sales strategies. Both parties should align the material planning in order to synchronize the material flow. This concept goes beyond the information sharing, the planning and control systems are integrated and coordinated through the supply chain. (Slack, 2006). “This could be by using vendor-managed inventories (VMI) or customer-managed ordering (CMO)” (Jonsson & Mattsson, 2009; p.107). *Vendor-managed inventory (VMI)* means “the supplier executes the customer’s procurement and material planning activities and enters replenishment orders into the customer's ERP system” (Jonsson & Mattsson, 2009; p.386). *Customer-managed ordering (CMO)* means “the customer is allowed to enter orders into the supplier’s ERP system” and the orders “are considered preliminary and must be checked and possibly modified by personnel at the supplier company before being approved and confirmed” (Jonsson & Mattsson, 2009; p.385).

Lack of information sharing throughout the supply chain increases risks to “incorrect forecast, temporary overstocking and resulting bullwhip effects” (Jonsson & Mattsson, 2009; p.107). If information is shared widely all over the supply chain, it can reduce high fluctuation of the bullwhip effect. For example, supply problems or shortages can be passed through downstream, then, customers can modify their sales plan. Sharing daily electronic *point-of-sales (POS) data* from retailers to upstream actors in the supply chain is a good example in order to make more accurate demand information and suppliers can be informed of the real market movements. (Jonsson & Mattsson, 2009).

Skjott-Larsen (2007) claims that "If the manufacturer allocates the scarce products in proportion to the amount ordered, the customers will order more than they actually need, hoping to secure a larger proportion of the scarce products. The effect of *shortage gaming* is that the manufacturer does not know, what the real demand is for these products, and therefore creates a bullwhip effect upstream in the supply chain" (p.54).

3.7.3 Collaborative Planning Forecast and Replenishment

"Improving the accuracy of your forecasts directly reduces the inventory-holding requirements that will achieve customer service-level targets" (Slack, 2006, p.229).

Jonsson and Mattsson (2009) mention about *collaborative planning forecasting and replenishment (CPFR)* concept which is aimed to create cooperative relationships between players in a supply chain for sale increase, effective material flows and less tied-up capital. The CPFR concept consists of five principles:

"

1. Collaboration within the framework of partnership relations and mutual trust.
2. Using common and agreed forecasts for their planning and activities. This is a first condition in order to synchronize material flow between companies
3. Exploiting core competencies in the supply chain regardless which company they are located in. Example is use of VMI.
4. Using common performance measurement system in the entire supply chain based on customer demands.
5. Sharing risk and utilities which arise in the supply chain. This will bring the positive mutual influence on behavior in the companies involved. If the total tied-up capital in a supply chain is reduced, retailers are motivated to improve their forecasting accuracy while manufacturers are motivated to improve their delivery precision." (p.108).

3.8 Supply Side Management

As mentioned in the previous section, reducing bullwhip effect in the supply chain is the important task for most organizations. Good collaboration and information sharing are required in all players of a supply chain, not only demand side but also supply side.

Effective supply management is a necessary condition in order to produce good outputs. In this section, supply strategies and supply contracts are introduced as the tools to support the collaboration between the company and their suppliers. Choosing the right suppliers is an important responsibility of procurement function but it is not only choosing. A company needs to maintain smooth supply and ensure the information flow between them and suppliers. (Slack, 2006).

3.8.1 Supply Strategies

The buyer-supplier relationships are affected generally by balance of power and interdependencies between two parties, regardless of competitive or partnership relations. If A depends on B more than B depends on A, then B has power over A. Consequently, it is assumed that power and interdependence issues will ground the choice for a supply strategy. (Caniëls & Gelderman, 2005; Jonsson, 2008).

Companies have to spend both time and resources to develop and maintain the partnership with their suppliers so this makes it is unreasonable to create the partner relationship with a large number of suppliers. Kraljic (1983) proposes a matrix with four characteristics of product/item; strategic, bottleneck, leverage and non-critical items, as a framework for developing supply strategies. In each square of the matrix, items are evaluated on their *supply risk (availability on the market);* few or more suppliers produce this item, and their *profit impact (significance for the company);* cost, quality or performance affects to the product. Gelderman and Van Weele (2003) adapts Kraljic's matrix by recommending several strategies within each quadrant. Some strategies keep the current position while others are moving to another position as shown in figure 10.

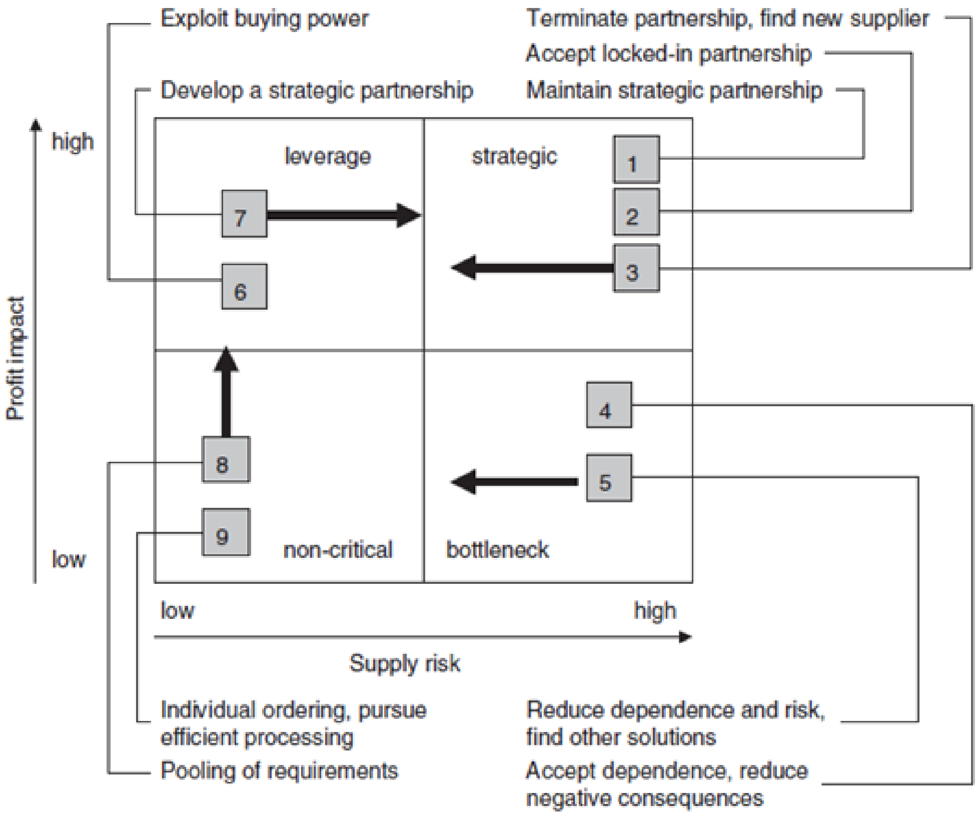


Figure 10 Kraljic's matrix with several strategies by Gelderman and Van Weele (Caniëls & Gelderman, 2005).

However, is it sufficient to develop the partner relationship only base on the characteristics of the item, or does the company needs other structures?

"Most companies do not have any established mechanisms to gauge the strategic potential of a supplier. Even worse, many companies are using the term "partner" in an inflationary way. Any high-performing supplier, or just a big one, will often be labeled as partner or even strategic partner" (Schuh, 2014; p.32). Schuh (2014) claims that a high strategic potential supplier should embrace the key which supports the company to have competitive advantage. Schuh (2014) introduces four indicators used to measure the high-level strategic potential of a supplier. The indicators and their definitions are shown in figure 11:

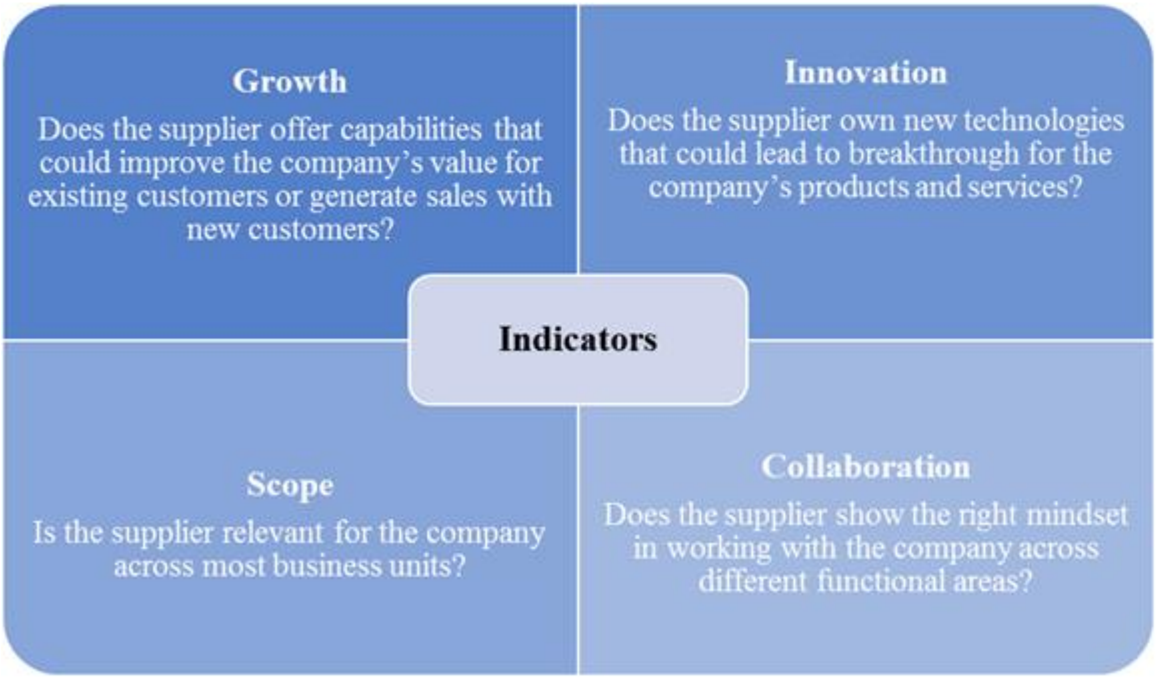


Figure 11 Indicators of high-level strategic potential supplier (Schuh, 2014).

3.8.2 Supply Contracts

Naturally, a high level of sourcing signifies that the procurement function becomes very critical for Original Equipment Manufacturers (OEMs); in order to control the intention. Respectively, many OEMs establish closely collaborating with the suppliers who provide their strategic components or products. (Simchi-Levi et al. 2008).

Development of supplier relationships is important for achieving efficient procurement strategies. Supplier relationships can occur in an informal form. However, to ensure effective supplies and deliveries, and synchronize the supply chain, supply contracts should be agreed. (Simchi-Levi et al. 2008). Dolcemascolo (2006) claims "I've often heard that the contract should be nothing more than a general agreement outlining the relationship at first. However, if the contract is too general, it will not serve any purpose other than to make both parties have a good feeling about the relationship"(p.100). Therefore, it is important that the contract identifies what are the responsibilities in both parties.

Simchi-Levi et al. (2008) mention about typical supply contracts which both parties will make an agreement on:

- Pricing and volume discounts
- Minimum and maximum purchase quantities
- Delivery lead times
- Product or material quality
- Product return policies

3.8.2.1 Risk sharing contracts

In a MTO supply chain, the buyer purchases items according to knowing customer demand or forecast while suppliers produce based on an order from the buyer. In this situation, the buyer takes all of the risk for keeping stock. At the same time, the buyer limits their order quantity because of the financial issues, but this leads to the out of stock risk. Consequently, if the supplier can share some risk with the buyer, it may create profit for both parties. (Simchi-Levi et al. 2008).

Buy-back contract and revenue-sharing contract are mentioned in Hochbaum and Wagner (2015); which lead to risk sharing between the buyer and the supplier. "In a *buy-back contract*, the supplier charges the buyer a fixed amount per unit purchased, but makes a (lower) per-unit payment to the buyer for each unit remaining at the end of the season. In a *revenue-sharing contract*, the supplier charges a fixed amount per unit purchased by the buyer, but the buyer gives the supplier a percentage of his revenue." (Hochbaum and Wagner, 2015, p. 957).

Simchi-Levi et al. (2008) also mention some contracts that help to increase benefit for both parties. "*Pay-back contracts* the buyer agrees to pay some agreed-upon price for any unit produced by the manufacturer but not purchased by the distributor. Clearly, this gives the manufacturer incentive to produce more units, since the risk associated with unused capacity is decreased" and "*Cost-sharing contracts* one important reason why the manufacturer does not produce enough is the high production cost. If somehow the manufacturer can convince the distributor to share some of the production cost, then, clearly, the manufacturer will have an incentive to produce more units" (Simchi-Levi et al. 2008; p.132-133).

3.8.2.2 Contracts with asymmetric information

In the short-lifecycle products, poor forecast always occurs as a consequent of a difficulty in uncertain demand. *Option or flexible contract* is introduced to reduce the Inventory risk. The buyer and the supplier have an agreement to purchase a certain number of product in the time period. Any extra quantity will be bought by the buyer at a different price. (Hochbaum and Wagner, 2015).

Normally, the buyer and the supplier share the same demand forecast. As a result, the supplier or the manufacturer will build their capacity based on the buyer's forecast. However, there is a possibility that buyer will enlarge its forecast or the forecast is higher than realized demand (Simchi-Levi et al. 2008). Simchi-Levi et al. (2008) mention about two contracts for achieving reliable information sharing:

Capacity reservation contracts: Buyer pays to reserve a certain level of capacity with the suppliers. The supplier designs the price list which motivates or convinces the buyer to reveal the true forecast.

Advance purchase contracts: Buyer and supplier make the firm commitment about the true forecast. Buyer pays the advance purchase price for the order place prior to build capacity. For additional order, buyer has to pay a different price.

Effective supply contracts can replace the traditional sourcing strategy, meanwhile each firm tries to maximize their own benefits, with *global optimization* which provides profit to the entire supply chain (Simchi-Levi et al., 2008). Nevertheless, firms should not select the contract based on costs, benefits, risks and relationships. It is important to consider the dynamics of external environment also. (Talluri and Lee, 2010).

3.9 Cause-and-effect-diagram

In order to identify and sort out the root causes of a problem a cause-and-effect-diagram can be created. This diagram is also known as *fishbone diagram* or *Ishikawa diagram.* After identifying the main causes of the problem, each cause must be studied separately in order to find the detailed causes of the main cause. A useful cause-and-effect-diagram usually contains several "bones" on the skeleton. (Bergman and Klefsjö, 1994; *McNeese, 2016*). "Cause-and-effect-diagram provide an excellent basis for problem solving" (Bergman and Klefsjö, 1994; p.239).

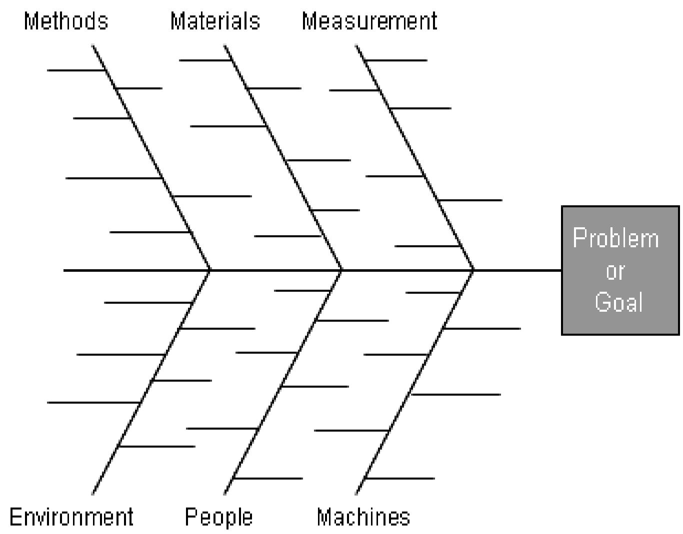


Figure 12 Cause-and-effect diagram (McNeese, 2016).

4 Analysis

Following sections provide the analysis of the interviews. This part has been separated into different sections in order to facilitate following up the research questions and gathered information. Section 4.1 describes the degree of customization and demand fluctuation of Sunny product. The analysis in section 4.2 and 4.3 study the first sub research question and focus on cost and lead time of material flow for the mechanical component. Transportation cost for shipping the mechanical components by using rail and sea transportation modes, which were calculated by authors according to invoices received from the logistics company are presented in section 4.2. The VSM and the problems identified from the VSM which were gathered during the brainstorming session will be provided in section 4.3. The second sub research question has been analyzed in section 4.4 which focuses on inventory management. In order to find out how collaborations between different parties in the supply chain can reduce bullwhip effect (third sub research question), demand side management and supply side management have been analyzed in section 4.5 and 4.6. The cause-and-effect-diagram provided at the end of analysis section aims to classify and structure the root causes of long lead time for mechanical parts, which have been identified.

4.1 High Degree of Product Customization

The Sunny product had ETO production environment from the beginning. The specifications of the product were set by the customer. Design of the product was based on the agreements between the lighting company and their customer, and also based on the customer demands. Today the product has a mixed production environment of ETO and MTO. After completing the design phase, and receiving the customer's approval regarding to the specifications, purchasing orders have been placed by the customer due to their demands. The product has been further developed, since the design work was completed; but the product structure and function which were decided during the first agreements maintain the same. High degree of customization for Sunny products makes the customer unable to provide forecasts. Regarding to uniqueness of the products, there are lack of product and order history; these issues also make the forecasts more complicated, and sometimes the customer only can guess the forecasts. Figure 13 shows the difference in customer order quantity during 2014 and 2015.

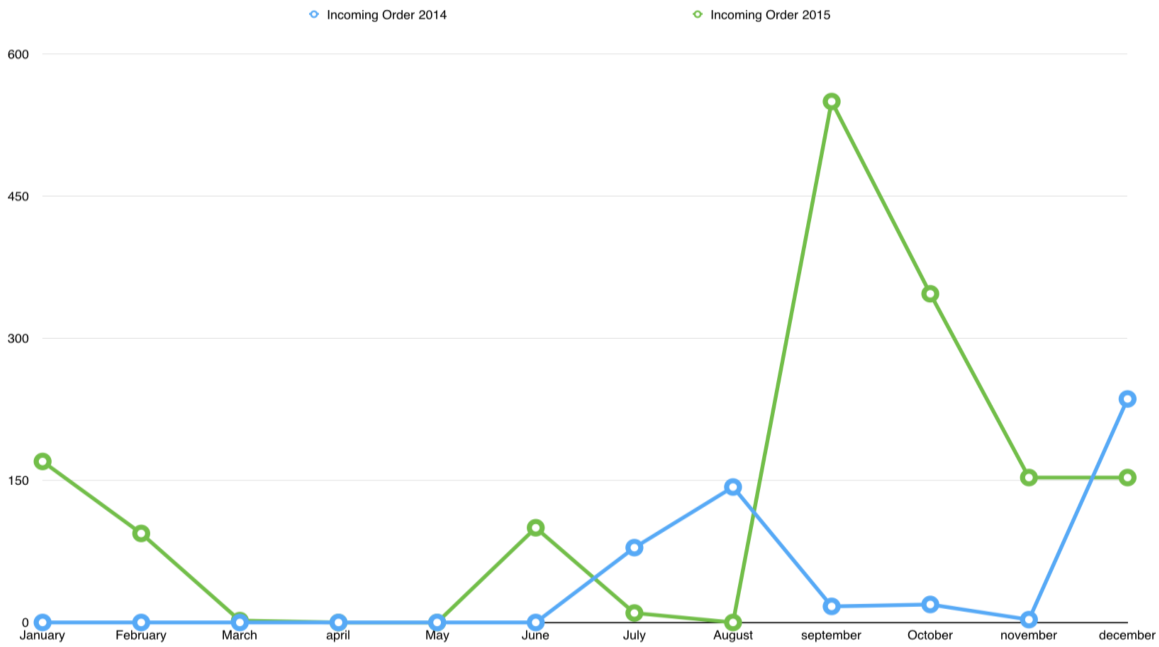


Figure 13 Graph of incoming customer orders.

The supplier of mechanical components also produced the parts in an ETO environment in the beginning of the development phase. The mechanical parts are unique and completely customized according to the lighting company's specifications. The component is produced according to orders today, so to say it has a MTO productions environment now. Beside the uniqueness of the mechanical components; these parts have very complex structure due to the tools used in the production and also number of the failures.

4.2 Transportation of the Mechanical Component

Today the lighting company is taking advantage of all four traditional transportation modes; air, rail road and sea. Each of the mentioned transportation modes have different lead times for instance; less than a week for air transport, 20 days for rail transport and 40 days for sea transport. The components are usually transported by truck from the supplier in China to harbour, airport or train station. The Chinese supplier has complete responsibility for this part of the shipment and also pays for the costs of truck transport. Afterward the components will be shipped to Gothenburg, by rail, air or sea transport. A logistic service provider company called Scan will take care of the shipments all the way from harbor, train station or airport in China to the lighting company in Gothenburg. So to say for each shipment the lighting company needs to use a combined transport of air-road, rail-road or sea-road which are managed and planned by Scan.

The mechanical components are shipped on pallets; one full pallet contains 150 pieces which is worth around 8025 USD. During last year the lighting company received four shipping orders from the Chinese supplier. One of last year's shipments was done by using air-road and three others were managed by sea-road combination. Today the lighting company is not interested in using air transport, because of high price of shipping regarding to weight of the mechanical components. Only 60 pieces were shipped by air; that shipment was the only solution the lighting company had to avoid shortage in the production. The Chinese supplier and the lighting company have agreement for shipping a batch size of 500 pieces from China to Sweden, however this agreement is not followed properly due to demand fluctuations in customer side. According to ordering history of the lighting company the shipping batches have always been less than 500 pieces.

Beside the mechanical components, the Chinese supplier ships other type of components to the lighting company in Gothenburg; for instance the shipments may include other components as well. But the mechanical components are usually considered as priority orders in order to predict late delivery. Newly the lighting company have started to use rail-road combination for shipments from the Chinese supplier. Only one shipping has been completed using this combination, the lighting company is considering the price and lead time of this shipment in order to decide whether to continue with sea-road transportation or change to rail-road mode; however it has been mentioned during interviews that the company prefer to take the cost of transportation into consideration.

Usually the payment for transportations occur after receiving the goods, but the period may differ when using different transportation modes. Cost and time of the transportation from China to Sweden limits the lighting company in choosing different transportation modes and makes the shipment less flexible. Cost and time issues also affect the management of defective parts. Today the lighting company is not able to return the defective parts because of the high cost of transportation in relation to the price of each mechanical component. The lighting company decide to scrap the defective parts and inform the Chinese supplier to include the defect quantity in next shipping order.

4.2.1 Transportation Cost

Table 3 provides the total transportation cost of mechanical components when using sea and rail transport. The costs have been calculated according the invoices received from Scan logistics company during 2015 and one train invoice received during 2016. The detail calculation is provided in the appendix I.

Table 3 Transportation cost using Scan logistics company.

Transportation Cost			
Number of Pallet (Mechanical Parts)	Sea Cost (SEK)	Rail Cost (SEK)	Difference (SEK)
1 (150)	1864.82	6544.44	4679.62
2 (300)	2479.65	10288.88	7809.23
3 (450)	3439.47	12833.32	9393.85
4 (600)	4334.3	16077.76	11743.46
5 (750)	5229.12	19322.2	14093.08
6 (900)	5493.94	20916.64	15422.7
7 (1050)	6283.77	23886.08	17602.31

Costs mentioned in the table 3 includes the truck transport from harbor or from train station to the lighting company. In case of shipment by train, the goods will be delivered to train station in Hamburg, Germany and then they will be transported further to the lighting company in Gothenburg by truck (details are shown in current state map by rail).

Comparison of the costs for using different transportation modes, makes it clear that it will be more cost efficient for the lighting company to use sea transport. However deciding whether to choose rail or sea is a time-cost trade off.

4.3 Extended Value Stream Map

According to the answers of questionnaire from Chinese supplier and Logistics Company, authors have created two current state maps; for sea and rail transportation, which give the clear picture of the information flow and material flow for mechanical components from raw material company in China until the lighting company in Sweden. Moreover, the information flow was separated from two current state maps in order to show the detail of queue time and number of information transfers between different parties.

4.3.1 Flow of Mechanical Components

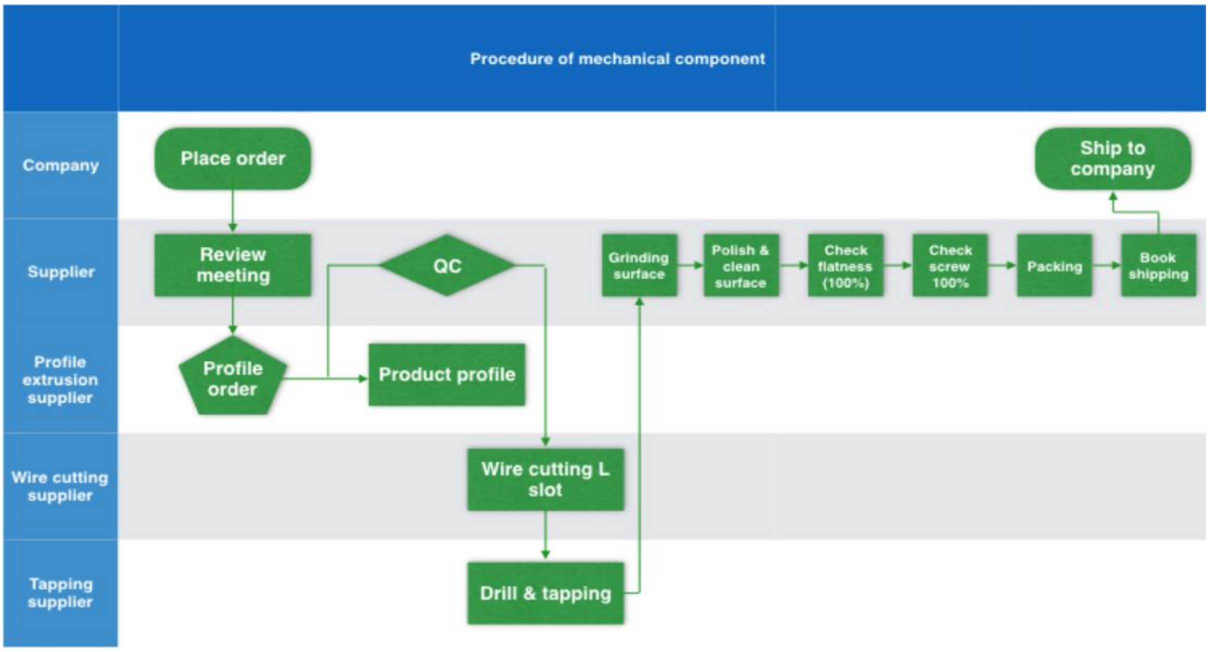


Figure 14 The procedure of mechanical component (source: Chinese supplier, 2016).

In order to create the correct value stream map, the flow of mechanical component has to be clarified regarding number of parties involved in different processes and which process belongs to which party. As shown in figure 14, production process of mechanical components, from raw material occurs at sub-contractor companies. These processes are wire cutting, drilling and tapping. Then, the mechanical components are moved to the Chinese supplier for implementing further processes; grinding surface until the last process. Finally, the finished mechanical components are packed and shipped to the lighting company. The whole production process takes 36-42 days, in the case that there is no aluminum in stock at the subcontractor.

4.3.2 Current State Map Definition

The current state map is adapted by authors to be suitable for the supply chain of the mechanical component. Some of these adaptions have been done due to limited data and the limitation of this thesis. In order to make these adaptions, metric definitions mentioned in section 3.4.3 have been changed. For example, value-creating time and non-value-creating time have been combined and are defined as production time. All metric definitions which are used in these current state maps are described in fact sheet and time table below.

Fact sheet

The fact sheet consists of queue time (Que.), production time (Prod.), waiting time (Wait.), batch size (BatchSize) and working time (Work.).

Queue time: includes the time from raw materials/components arrive the plant until the manufacturing can start.

Production time: includes the time from start manufacturing raw materials/components until finish packaging those parts. This production time consists of both value creating time and non-value-creating time.

Waiting time: includes the time from finish packaging components until transport comes to pick up those components to customers or to the harbour/train station.

Batch size: is the number of raw materials/components which have been manufactured at once.

Working time: is the amount of day per week that the company have manufacturing. Number of working days/week is different in China, Sweden and during the shipping time. For example, 6 working days each week have been considered for China, 7 working days each week have been considered for boat transportation and 5 working days per week have been considered for the lighting company in Sweden.

Time table

In the current state map, the time table at the bottom consists of in-plant time (IP), transport time (Tran.) and total time.

In-plant time: there are two conditions

- When raw materials/components are at the manufacturing place, in-plant time includes queue time, production time and waiting time.
- When components are at the harbor or train station, in-plant time includes the time from components are unloaded from one transport until those components are uploaded again on another planned transport.

Transport time: includes the time since a transport, which carries raw materials/components, moves out from manufacturing place/harbor/train station until the transport arrives manufacturing place/harbor/train station of destination

Total time: includes in-plant time and transport time.

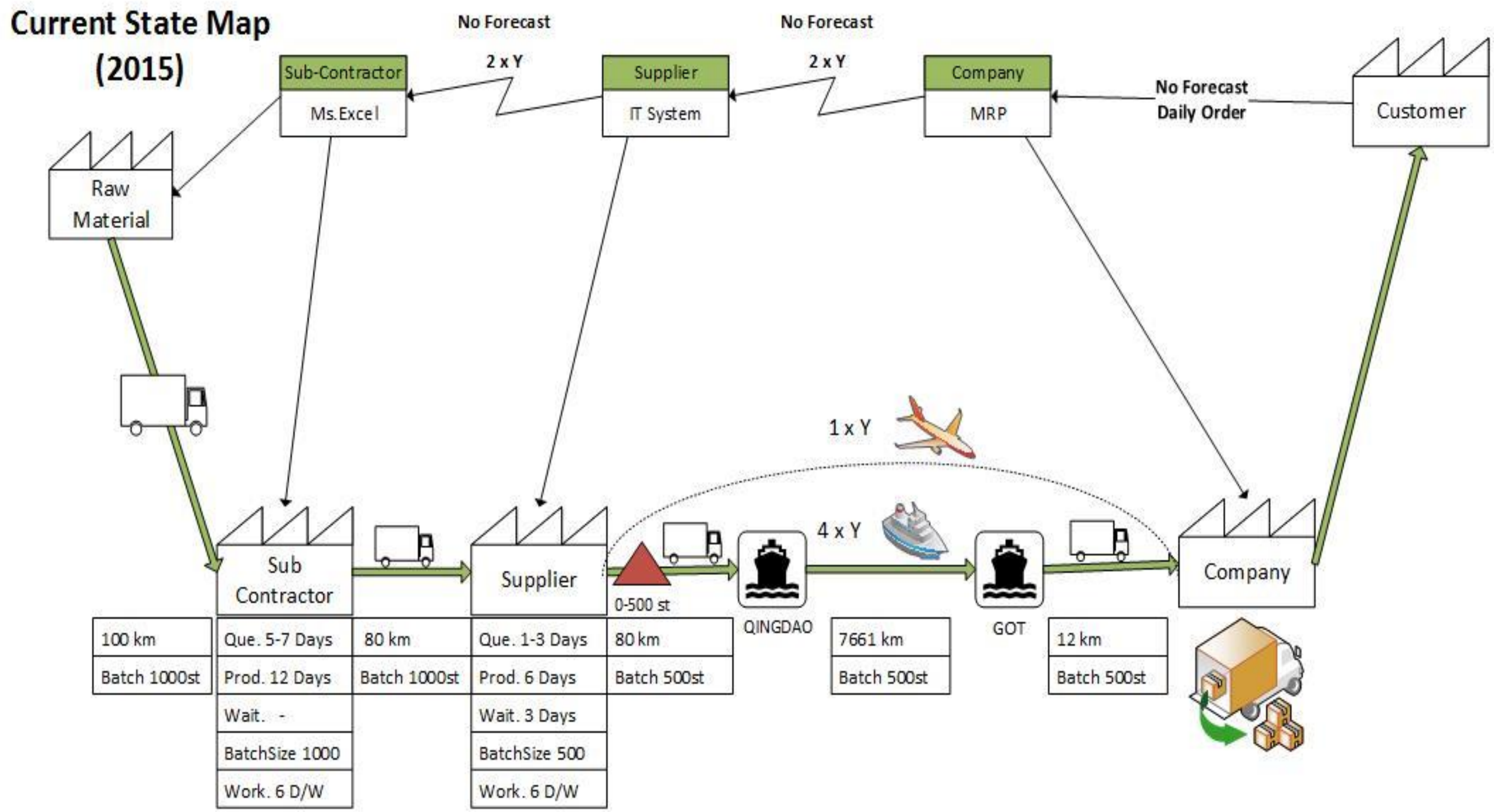
4.3.3 Current State Map for Sea Transport

The current state map provided in this section is showing the current situation of the supply chain for the mechanical component. The data included in the current state map is from 2015. Main part of the findings from interviews with the Chinese supplier has been described in this map.

Information flow from the customer to the raw material company is visualized at the top of this current state map. The information flow shows that there is no forecast provided from the customer to the lighting company and neither from the lighting company to the Chinese supplier. Three parties in this supply chain; the lighting company, the Chinese supplier and the sub-contractor company, use different IT system. The arrows between the boxes in the information flow show the type of information sharing (providing forecast and purchasing order) between companies involved in this supply chain. The straight arrow shows the manual information while the thunder-shaped arrows show the electronic information.

Material flow of the mechanical component from the raw material company to the lighting company is shown at the middle of the current state map. Different transportation modes used in this supply chain are shown as figures (truck, boat, and plane). During 2015, the lighting company decided to ship the mechanical component by air once which is shown in the material flow (1 x Y). Furthermore, the mechanical component were shipped by boat to Sweden four times (4 x Y). The red triangle in the material flow shows the safety stock of mechanical components at the Chinese supplier (0-500 pieces). The definition of each term stated in the boxes within the material flow is provided in the fact sheet (section 4.3.2).

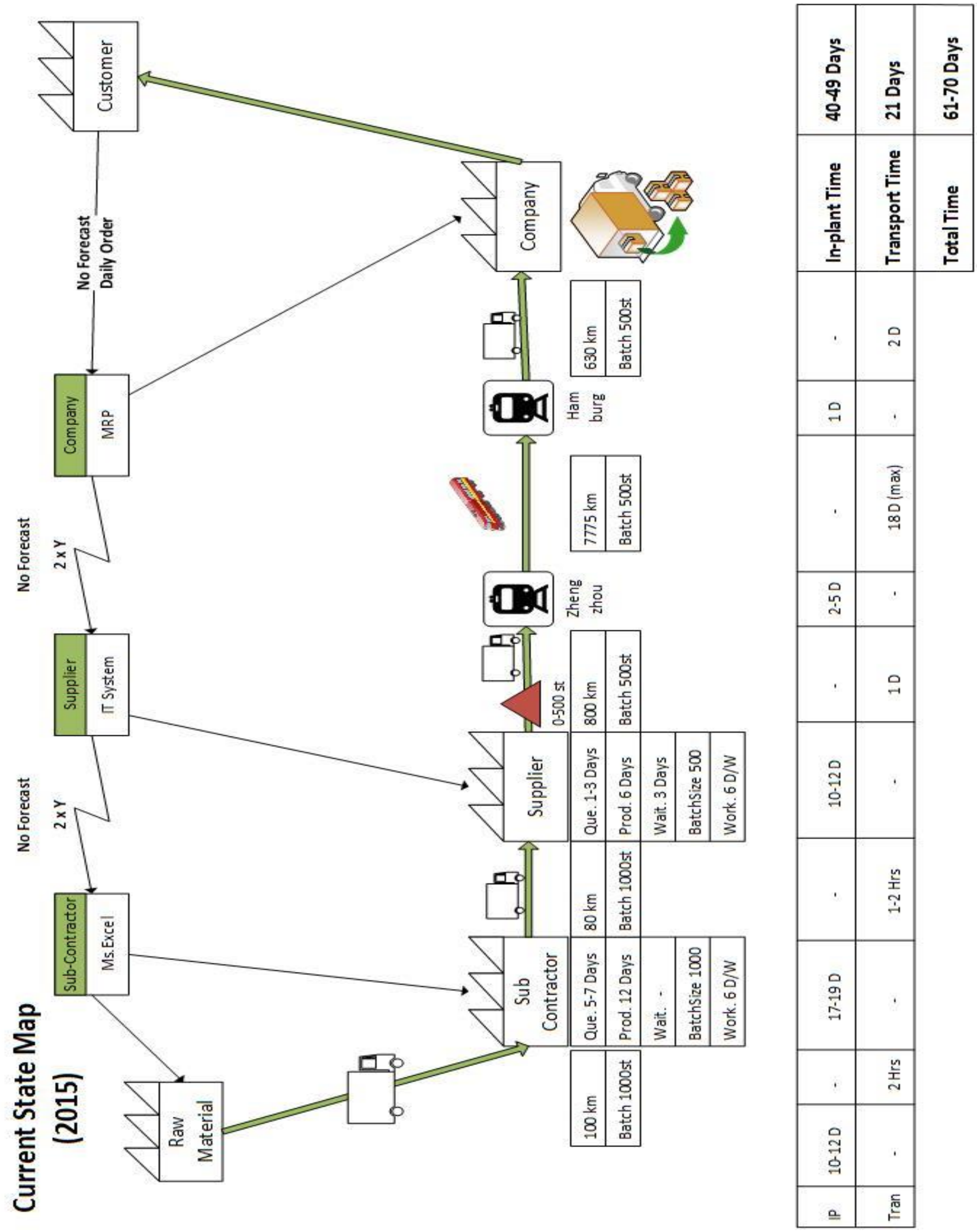
The stair at the bottom of the current state map shows the time table for each process included in the material flow (definitions are provided in section 4.3.2). The total time of the material flow for this mechanical component is shown at the right side of this time table (84-90 days).



IP	10-12 D	-	17-19 D	-	10-12 D	-	4 D	-	3 D	-		In-plant Time	44-50 Days
Tran	-	2 Hrs	-	1-2 Hrs	-	1.5-2 Hrs	-	40 D (max)	-	0.5 Hr		Transport Time	40 Days
												Total Time	84-90 Days

4.3.4 Current State Map for Rail Transport

Most of the information in this current state map is same with the current state map for sea transportation (section 4.3.3). This current state map shows the total time (61-70 days) of the material flow for mechanical component by using rail transportation.



4.3.5 Information Flow Map

Information flow and queue times cannot be shown in detail in the VSM; therefore a separate map have been created in order to visualize the flow of information all the way from the customer company to raw material company.

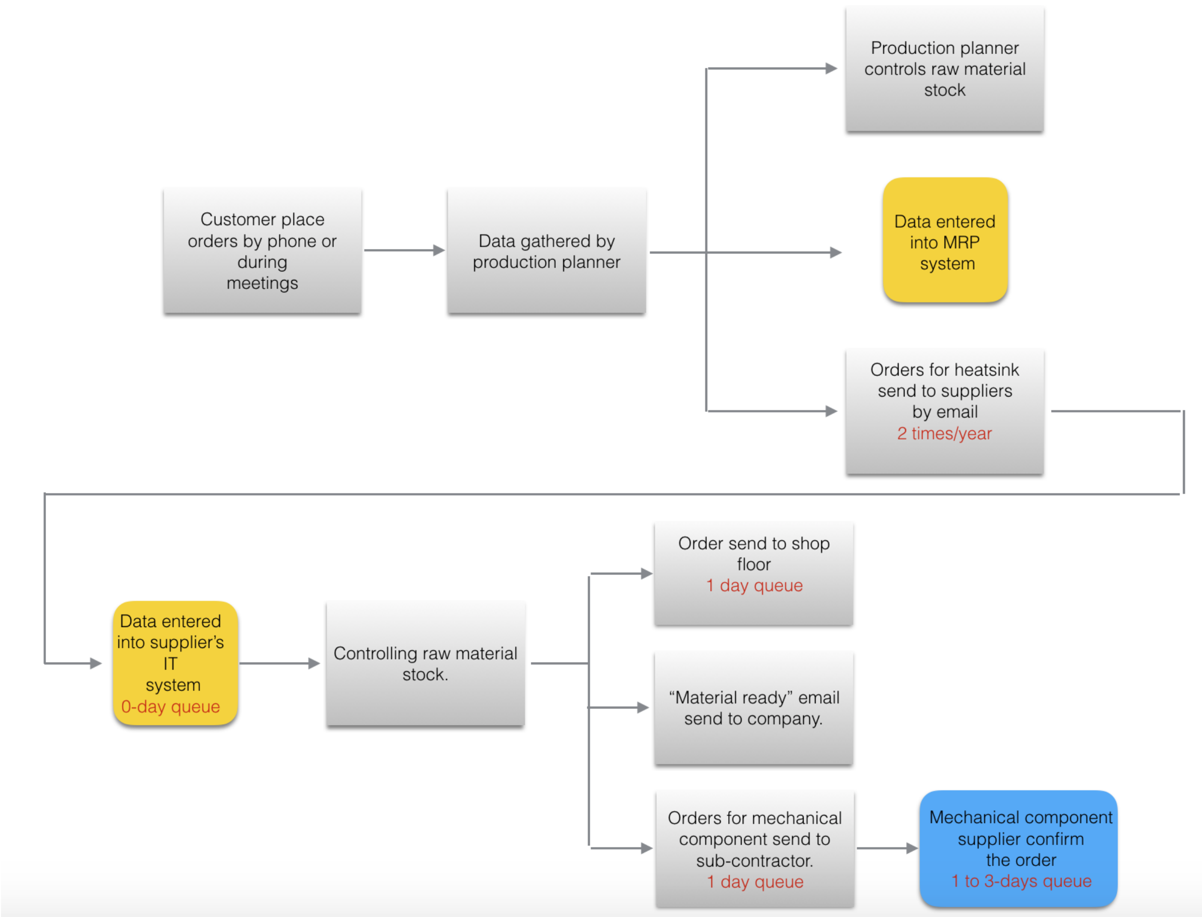


Figure 15 The information flow map.

The information flow process map metrics' table aims to identify the queue time and number of information transfers in each company in relation to the information flow map. As it can be seen in the map; there are no queue time for information flow in the lighting company and the information transfer two times, for instance once from the customer to the lighting company and one from the lighting company to the Chinese supplier. Considering the Chinese supplier, it takes one day for this party to put orders for mechanical components to the sub-contractor. Number of information transfers is two at the Chinese supplier which refers to receiving information from the lighting company and the information send to the sub-contractor. Furthermore it takes one to three days for the sub-contractor to confirm the orders send from the Chinese supplier, and the transfer of information occurs only once between the Chinese supplier and the sub-contractor company.

Table 4 Information flow process map metrics.

Organization	Queue Time	No. of Information Transfers
The lighting company	0 day	2
The Chinese supplier	1 day	2
The sub-contractor company	1-3 days	1
Total	2-4 days	5

<u>Problems Identified in the Information Flow</u>

No considerable queue time has been identified from the information flow that can affect the lead time of the mechanical parts. Considering some factors can improve the information flow between different parties or even have positive influence on the responsiveness of the supply chain. Increasing the number of information transfers is one of these factors. Parties must considering sharing information back and forth regarding to forecasts and raw material stock levels. For example if the lighting company keeps the Chinese supplier up to date regarding to future demands; the Chinese supplier can ensure having enough components in their inventory in order to reduce the lead time to the lighting company. Another factor that can be considered within information flow is to make a connection between information transfers from the customer to information transfers from the Chinese supplier. This argument somehow supports the previous mentioned argument regarding to increasing the number of information transfers. Figure 16 shows the link which is missing in the information flow all the way from customer company to the Chinese supplier.

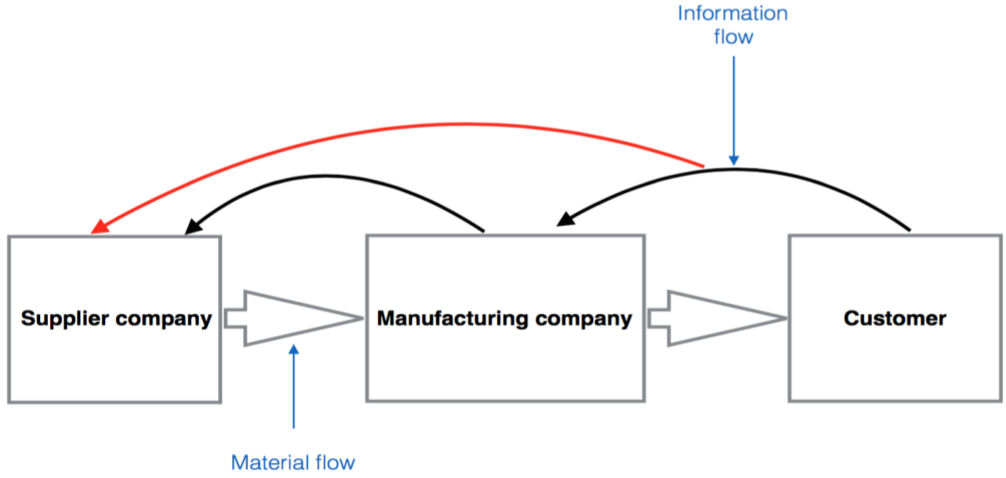


Figure 16 The link between information flow.

4.3.6 Problems Identified During the Brainstorming Session

During to the brainstorming session, authors asked two questions from participants regarding the current state maps; what needs to be improved or changed in the current state map? And what is good to keep in the current state map?

The points mentioned in the table 5 are the ideas which were gathered during the brainstorm session that are directly transcribed from collected post-its. These are going to be considered when creating the FSM and implementation plans which are provided in the recommendations section.

Table 5 Ideas gathered during the brainstorming session.

What needs to be improved or changed in the current state map?	What is good to keep in the current state map?
1. The Chinese supplier provides good quality for mechanical part.	1. Customer should provide better forecast to the company.
2. The company has good relationship with Chinese supplier.	2. The company should improve information flow between Chinese supplier and subcontractors.
3. It is easy to implement changes in the current state map.	3. All parties in the supply chain should implement standardized IT system and material planning method.
4. Boat transportation price is good.	4. Inventory should be managed effectively in the whole supply chain. - The company should calculate maximum inventory level and reordering point - The Chinese supplier should keep SS for mechanical component - Subcontractor should keep safety stock for raw material
5. At present, the company has secure supply chain and lead time.	5. The company should negotiate new prepayment term with the Chinese supplier and the customer.
6. The current state maps are applicable with other products in the company.	6. The company should secure lead time from the Chinese supplier.

4.4 Inventory of Mechanical Components and Finished Goods

When considering the stock level for mechanical components; the lighting company bases the customer service level on NL01 agreement, which is provided in the appendix II of this thesis (numerical service level is 97%). The lighting company prefers to keep maximum 1500 pieces of the mechanical components in raw material inventory because of issues related to the cash flow and limited space in the warehouse. According to interviews best strategy for choosing a reordering point for replenishment of the mechanical component's inventory, is to base the decision on forecasts.

As mentioned before, the lighting company is keeping finished goods inventory for the customer. Today the customer pays for 24 pallet places, but the lighting company is trying to reduce the number of pallets to 14. Payment for finished goods inventory occurs quarterly, the customer pay 7200 SEK each time. There are no agreements between the lighting company and the customer regarding to limitations or maximum number pallets of finished goods which the company accepts to keep in their inventory.

4.5 Demand Side Management

The customer for Sunny product is a Swedish company which is specialized in lighting technology. They sell the product to end users both in Europe and USA. The size of customer's organization is smaller than the lighting company but their organization is growing.

4.5.1 Customer Relations

In the past, there were no contracts or agreements between the lighting company and the customer. Customer order quantity was not fixed in specific number; while the customer prepaid for purchasing raw materials. Actual order quantity had high variation in different periods along the whole year.

In order to clarify everything, the lighting company and the customer have created an agreement together on December 2015; but the agreement has not been signed yet by any of these parties and there is no guarantee that the agreement will be signed in future. It has been stated in the agreement that the customer demand forecast for 2016 is 5000 units. The lighting company will follow up the agreement during the first six month of 2016 in order to ensure the customer order can reach 5000 units as it has been agreed. The reason for following up the agreement is the cost of purchased material for the lighting company; for excess purchased material, in case the actual orders for 2016 will not fulfill the 5000 units' agreement. Detail conditions about this payment have been mentioned in the agreement paper. Moreover, the lighting company has set a new ordering frame for the customer, which indicates that customer orders cannot be less than 500 units in each occasion. However, there is no indication about this ordering quantity in the agreement, it was a discussion between two parties without any formal confirmation. There is a customer payment agreement between the lighting company and the customer that is not stated in the agreements paper also which indicate 30 days payment for hardware and 14 days payment for design work.

4.5.2 Customer Forecasts

Forecasting the demand has been a big challenge for the customer according to the nature of the product; innovative and new so the market is unpredictable. The product family has continuously been developed during past few years; some models were added and some were cancelled. Today the customer has hired professional consultants in order to help creating a suitable forecast method for Sunny products. The forecast model, which the customer is using, follows 6 weeks pattern. The lighting company and the customer have weekly meeting regarding to the forecast for next 6 weeks, the 6 weeks purchasing order is placed during these meetings also. Nowadays, even the customer can provide more detailed forecast but the lighting company has not decided to buy any raw materials based on the forecast and wait until receiving the purchasing order from the customer.

Following graph shows the demand fluctuations of Sunny product family since the lighting company started selling them.

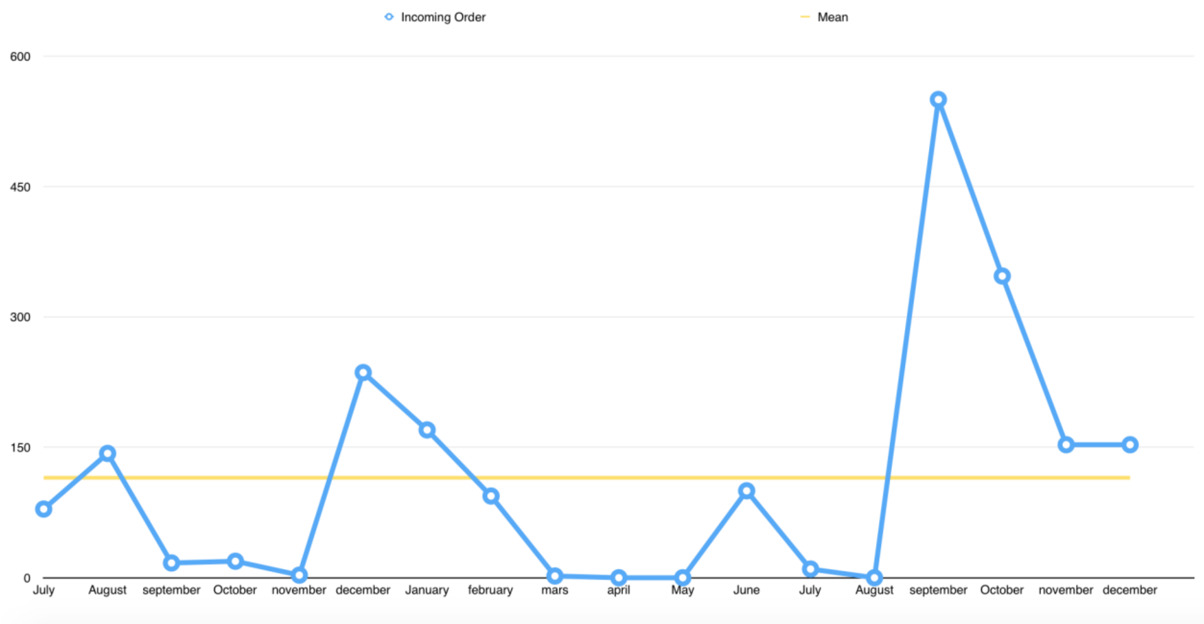


Figure 17 Graph of demand fluctuations for Sunny product family (July 2014-December 2015).

4.5.3 Information Sharing with Customer

The customer use Monitor as MRP system, however this system is not connected with the MRP system of the lighting company. It has been mentioned during the interview that it is possible to connect IT system between them but the information format has to be changed into the same alignment first. The customer usually doesn't share any information regarding to sale plans or other information which can affect the demand changes, they only provide forecasts and actual orders.

4.6 Supply Side Management

The lighting company is outsourcing many components to global suppliers, except the PCB which is produced inside the factory. For the mechanical part, it's very hard to find suitable suppliers inside of Sweden. The lighting company have been contacting many suppliers both in Scandinavia and China regarding to production of the mechanical parts; but is has been hard for other suppliers to produce this component due to sensitivity and complexity of the design. Moreover, in Europe, the aluminum costs two times higher in compared to China; which makes the outsourcing more profitable for the lighting company.

4.6.1 Supplier Relations

The Chinese supplier has a big organisation which produces different types of products. Beside the good price they provide for producing the mechanical parts, they are very flexible and are able to produce small volumes based on the customer's demands. The lighting company and the Chinese supplier have collaboration for long time before the Sunny products were introduced. However, there is no contract or agreement between these two parties. They have also been cooperating along the developing phase of the mechanical part. In 2013, the lighting company decided to create joint-venture with this Chinese supplier in order to follow the requirements of one big customer in China.

People from the lighting company usually have face to face meeting with Chinese supplier, four times a year. The lighting company pays for the visits in China; cost of these meeting has been estimated around 30 000 SEK for one travel. Chinese supplier also visits the lighting company in Sweden; during last year they paid a visit in Sweden one time and the lighting company took responsibility for the costs of this visit also.

Specialty of the Chinese supplier is in metal molding; beside the mechanical components, this supplier provides several other components, which are used in Sunny products and also in other product families produced in the lighting company. The lighting company is one of several customers of the Chinese supplier, but it is the only lighting company which collaborates with them. Today approximately 60% of the sales of Chinese supplier come from this lighting company. The lighting company has high trust on the Chinese supplier, specially regarding to the quality of the mechanical part. There are no documented agreements or contracts between these two companies and all the relationships are managed based on the trust building between these two parties. Beside the good quality of the products provided by this supplier; there is another strong reason for the lighting company to continue collaboration with them. There are some tools which are used for assembly of the Sunny products; and these tools are provided by the Chinese supplier. The price of these kind of tools in Sweden is around 1 000 000 SEK which is much higher in compared to the price that the Chinese supplier provides (around 100 000 SEK). Other factors that has been taken into consideration by the lighting company for choosing the suitable supplier were lead time, customization of the products and product cost.

Another factor which makes the lighting company attached to the Chinese supplier is the development of the lighting company in China. The lighting company is growing their own department in China; this department is located inside of the Chinese supplier's company and the contact person in supplier's company, is also one of the board members of the lighting company in China. Today the Chinese supplier owns 30% of the share for lighting company's division in China.

The lighting company and the Chinese supplier have 30%-70% payment agreement today; so to say the lighting company pays 70% of the price of purchased components when ordering material, and 30% when the goods are delivered. Before this agreement, the lighting company prepaid 100% of the price. The lighting company have discussed about signing agreements with the Chinese supplier, but it has been unclear for people in the company whether to continue collaboration with same extent as before or move some components to other alternative suppliers.

4.6.2 Information Sharing with Supplier

Earlier the lighting company faced some communication barriers when contacting the Chinese supplier, because the staff were not skilled in English. Today this problem has been solved and the lighting company faces no difficulties during Skype or face to face meetings with the Chinese supplier.

The Chinese supplier has always asked the lighting company for the Sunny product's forecast however, the company has never provided them. Although the lighting company got the forecast for 2016 from the customer, the company doesn't have confidence with these number so they decided to not tell anything to the Chinese supplier. Moreover, the Chinese supplier has no information about the stock of mechanical part at the lighting company.

The Chinese supplier has developed their own internal IT system, this IT system is neither connected to the MRP system of the lighting company nor to the Chinese sub-contractors. The only possible way now to transfer information through the IT system from the lighting company in Sweden to the Chinese supplier, is to let the Chinese supplier check the monitor at the lighting company in China.

Regarding to feedback system from the lighting company to the Chinese supplier; there are no defined frameworks and no specific person is assigned to take responsibility of the feedbacks.

4.7 Causes of Long Lead Time for Mechanical Component

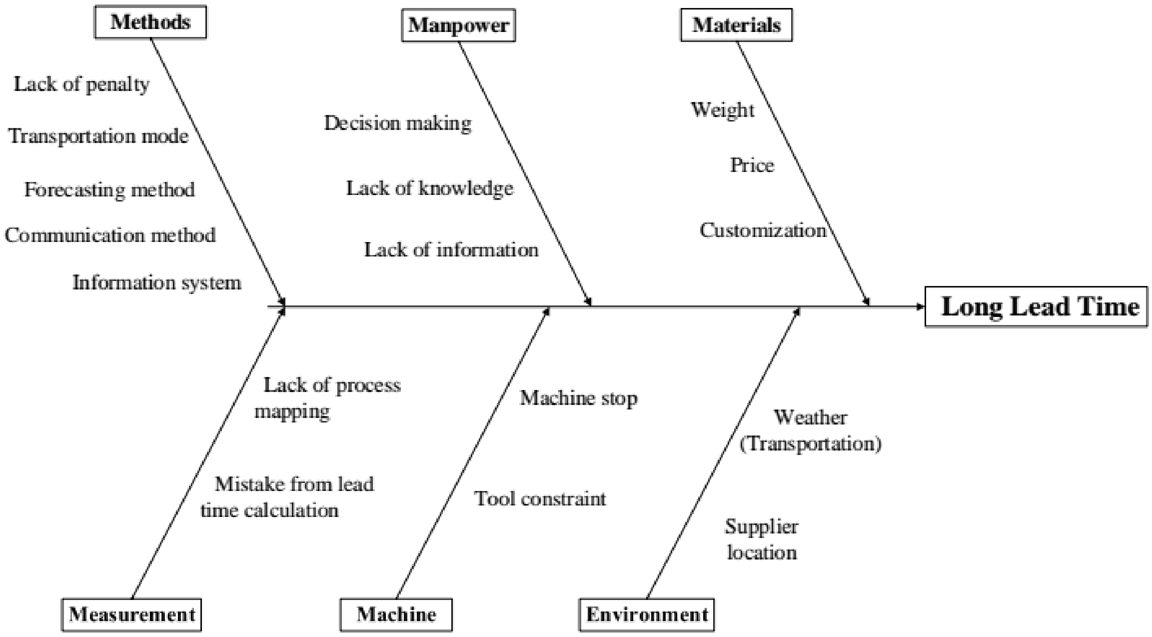


Figure 18 Cause-and-effect diagram for long lead time of mechanical components.

Considering the interview analysis; authors have identified several root causes which can increase the lead time of mechanical components as shown in figure 18.

Among the causes identified in the cause-and-effect diagram, methods and measurement are the issues which were mentioned most during the interviews. These causes which are mostly related to supply chain will be considered by authors in this thesis. The recommendations of this thesis will also be linked to these issues.

5 Recommendations

Comparison of theories and analysis show that there are many identified problems for the lighting company to refine their supply chain responsiveness of mechanical component. In this section, FSM is constructed regarding author's analysis and a brainstorming session with people in the lighting company. Furthermore, following sections will provide two different implementation plans for the Identified Problems. Aim of dividing the implementation plan into two groups is to clarify which points can be implemented in short term and which ones belong to long term implementation strategy.

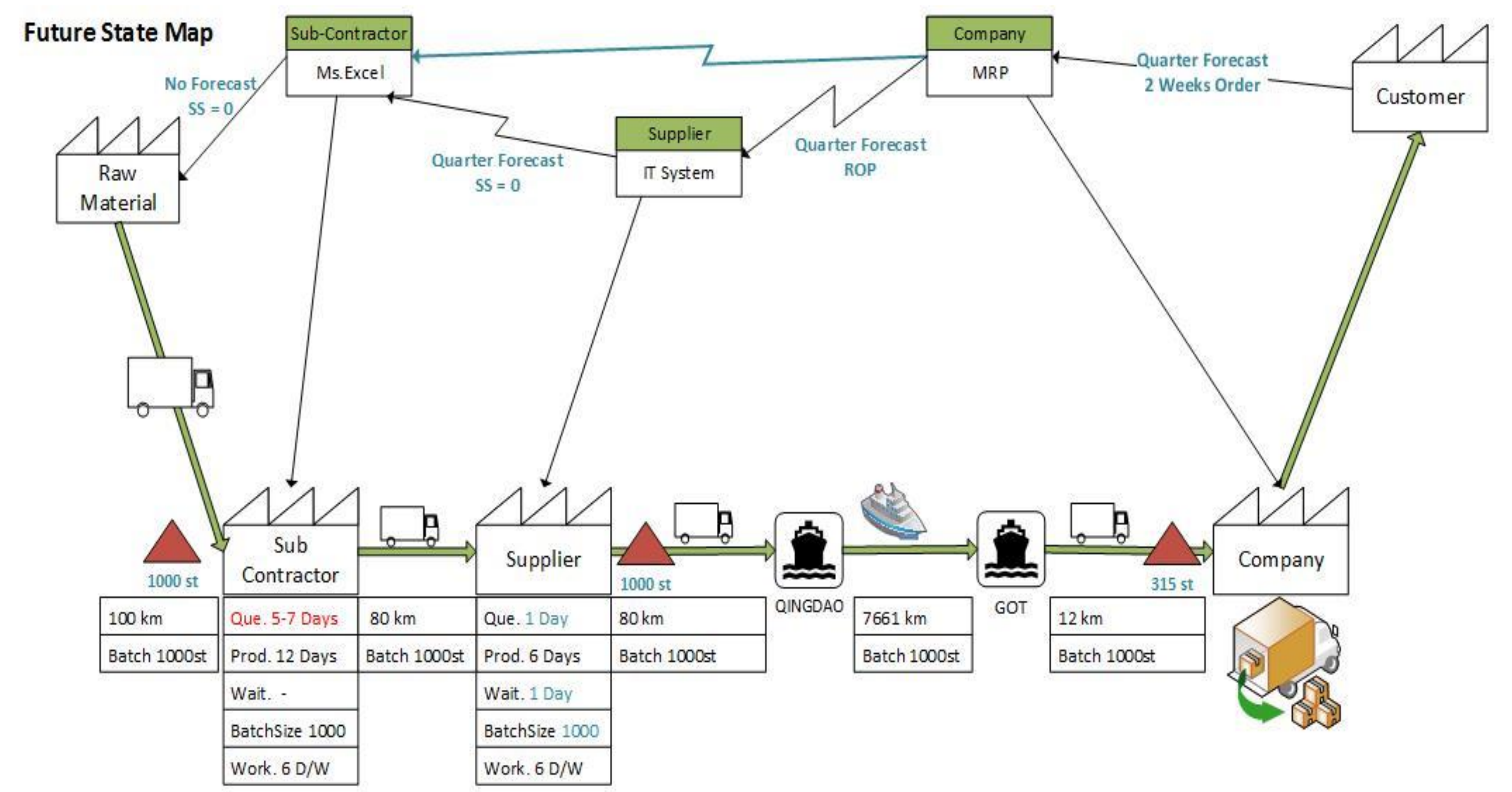
5.1 Future State Map

The FSM has been created by considering the analysis in section 4. In order to improve the information flow; a link has been added between the lighting company and the subcontractor in the information flow. Furthermore, quarter forecast and ROP have been added to the information flow.

In order to reduce the lead time in material flow; SS (1000 pieces) has been considered for the raw material at subcontractor site. Furthermore, the capacity of SS for mechanical components in Chinese supplier site has been increased from 500 pieces to 1000 pieces. At the lighting company, 300 pieces of SS have been considered to reduce the risks of shortages in the inventory. When estimating the capacity of the SS in the lighting company, the maximum inventory capacity and the lead time of mechanical components were considered. However, it should be considered that increasing the inventory level in the supply chain equals to increased tied up capital for parties involved in the chain, therefore improving the information flow, securing the customer forecasts, and sharing the forecasts through whole supply chain can help to keep the low inventory level and decrease the demand for keeping SS. The batch size at Chinese supplier has been changed from 500 pieces to 1000 pieces in the FSM. According to interview analysis this change will not affect the production time at the Chinese supplier site. Moreover, que time and waiting time at the Chinese supplier have been changed from maximum three days to one day.

Sea transportation has been chosen as the most suitable transportation mode, this decision was made by considering the costs and lead time of transportation all the way from China to Sweden. However, choosing rail transportation would reduce the lead time of the mechanical component and increase the responsiveness of supply chain. The decision for choosing sea transportation aims to compensate with the inventory cost.

For emphasizing the new total time after implementing the changes mentioned above, blue color has been used in the stairs at the bottom of the FSM. The total time covers the period since the lighting company send the purchasing order to the Chinese supplier until the mechanical parts arrive at the company. Considering the SS at the supplier site reduces the in-plant time and transportation time in China from the total time, and decreases the time from 90 days to 48 days.



IP	10-12 D	-	17-19 D	-	8 D	-	4 D	-	3 D	-	**In-plant Time**	**7+1(truck)**
Tran	-	2 Hrs	-	1-2 Hrs	-	1.5-2 Hrs	-	40 D (max)	-	0.5 Hr	**Transport Time**	**40 Days**
											Total Time	**48 Days**

5.2 Short Term Implementation

The short term implementation plan and recommendations have been created by authors after classification of the ideas gathered during the brainstorming session. The plans provided in short term implementation section were categorized as L and M after the brainstorming. Pictures provided in the appendix III of this thesis describe how the ideas were classified to create a short term and a long term implementation plan. However authors decided to also include their own ideas in implementation plans. This decision was made in order to consider all the problems and issues identified according to interviews and analysis and also provide different choices to the lighting company by calculating the ROP and creating two material planning (appendix IV). It has been decided to categorize different plans and recommendations in tables. The tables make the follow up of plans easier for reader and it takes less time for people inside the lighting company to find out the contribution of identified issues with articles and previous researches.

Recommendation 1: collect quality defect data

Identified Problems	Source
Not keeping data for amount defective components received from the Chinese supplier.	• Dolcemascolo (2006) indicates in order to determine the SS, a safety percentage must be considered which is “based on supplier reliability, quality, and delivery performance” (p.108). • Safety stock (SS) is a countermeasure, which supports supply chains performance, when facing forecast errors and demand uncertainties. (Sachs, 2015; Skjott-Larsen, 2007; Jonsson, 2008; Dolcemascolo, 2006; Toomey, 2000; Simchi-Levi et al. 2008). • Not keeping more than buffer capacity is one step for achieving responsive supply chain (Fisher, 1997). • Simchi-Levi et al. (2008) mention about typical supply contracts which include quality of material and components provided by suppliers.

Recommendation 2: improve information flow

Identified Problems	Source
Lack of sharing point-of-sale throughout the supply chain.	• Jonsson & Mattsson (2009) state that sharing daily electronic point-of-sales (POS) data from retailers to upstream actors in the supply chain is a good example in order to make more accurate demand information and suppliers can be informed of the real market movements.
Lack of plan alignment.	• Slack (2006) mentions that it is significant to communicate frequently between supplier and customer about change in plans, material movements, stock levels and other sales strategies. • Both parties should align the material planning in order to synchronize the material flow. (Slack, 2006).
Lack of direct contact with subcontractors.	• Brainstorming session (2016-04-29) • Slack (2006) mentions that it is significant to communicate frequently between supplier and customer about change in plans, material movements, stock levels and other sales strategies. Both parties should align the material planning in order to synchronize the material flow.
Insecure lead time when putting the purchasing order	• Brainstorming session (2016-04-29)

Recommendation 3: consider new conditions for customer and sign the agreement with the customer

Identified Problems	Source
The agreement was created but it has not been signed.	● Simchi-Levi et al. (2008) mention that to ensure effective supplies and deliveries, and synchronize the supply chain, supply contracts should be agreed.
The agreement lacks some conditions *Recommendation:* - *Condition for purchasing quantity* - *Condition for maximum finished goods inventory level*	● Dolcemascolo (2006) claims "if the contract is too general, it will not serve any purpose other than to make both parties have a good feeling about the relationship" (p.100). ● Simchi-Levi et al. (2008) mention about typical supply contracts which both parties will make an agreement on, including 1) Pricing and volume discounts 2) Minimum and maximum purchase quantities 3) Delivery lead times 4) Product or material quality 5) Product return policies
The customer provides uncertain forecast. *Recommendation:* - *Secure the customer forecast for eight weeks* - *Consider payment from the customer for air transport when the actual order excess the forecast*	● Brainstorming session (2016-04-29) ● "Improving the accuracy of your forecasts directly reduces the inventory-holding requirements that will achieve customer service-level targets" (Slack, 2006, p.229). ● Jonsson and Mattsson (2009) mention about *collaborative planning forecasting and replenishment (CPFR)* concept which is aimed to create cooperative relationships between players in a supply chain for sale increase, effective material flows and less tied-up capital. ● Based on the analysis, it can be mentioned that the forecasts are not equal to actual orders. Sometimes the actual order is more than the provided forecast. In order to avoid shortage in production and late delivery, required raw material must be shipped by air. In this case the customer must be responsible for paying the extra transportation cost.

Recommendation 4: manage transportation

Identified Problems	Source
Uncertain decision for most profitable transportation mode. *Recommendation:* - *Choose sea transportation mode*	• Based on the analysis, cost efficiency is the most important criteria for choosing transportation mode of mechanical part. • As shown in the *table 4*, *Transportation Cost Using Scan*, rail transportation cost is more expensive than sea transportation cost in all the case of pallet number. • Brainstorming session (2016-04-29)
Long waiting time for truck transportation at Chinese supplier. *Recommendation:* - *Reduce from three days to one day*	• Current state map 2015 (section 4.3.3-4.3.4) • Brainstorming session (2016-04-29)

Recommendation 5: manage inventory level within whole supply chain

Identified Problems	Source
Not considering a SS in the lighting company. *Recommendation:* - *Keep 315 pcs of mechanical component in the SS*	• Safety stock (SS) is a countermeasure, which supports supply chains performance, when facing forecast errors and demand uncertainties. (Sachs, 2015; Skjott-Larsen, 2007; Jonsson, 2008; Dolcemascolo, 2006; Toomey, 2000; Simchi-Levi et al. 2008). • Müller (2011) describes; "perhaps the easiest, but certainly not the least expensive, method of reducing supply chain risks is to have more safety stock. It's a tradeoff. More buffer stock, less risk but at a higher cost—less safety stock, more risk of stockouts but at a much lower cost" (p. 238). • Many supply chain problems can be addressed by considering SS. (Sachs, 2015; Skjott-Larsen, 2007; Jonsson, 2008; Dolcemascolo, 2006; Toomey, 2000; Simchi-Levi et al. 2008). • Brainstorming session (2016-04-29) • Calculation will be shown in appendix IV • FSM, 2016 (section 5.1)
Not considering raw material SS at sub-contractor company. *Recommendation:* - *Keep 1000 pcs of raw material in the SS*	• Brainstorming session (2016-04-29) • FSM, 2016 (section 5.1)
Not sharing SS with the Chinese supplier.	• There are other objectives which can influence supply performance such as; improving information sharing and collaborations in supply chain, "involving suppliers in new product development" and "sharing safety stocks of critical items with suppliers" (Skjott-Larsen, 2007; p. 359). • In order to make inventory management more efficient; companies using offshore suppliers need to maintain "a very low work-in-progress inventory to minimize excess and obsolete inventory"; on the other hand key suppliers need to keep safety stock in order to become more responsive to customer orders (Skjott-Larsen, 2007; p.360). • In order to secure the performance of global supply chains; safety stocks need to be maintained at suppliers plants also (Skjott-Larsen, 2007).

Lack of efficient way in material planning *Recommendation:* - *Consider reordering point at the lighting company*	● Material planning has direct effect on inventory level and aims to synchronize supply and demand of materials. (Jonsson & Mattsson, 2008). ● Brainstorming session (2016-04-29) ● Example of ROP and MRP will be shown in appendix IV

5.3 Long Term Implementation

As it was mentioned in the last section; creating the long term implementation plan was according to classification of ideas gathered during the brainstorming session. The plans provided in this section are those which were classified as H (pictures regarding to categorizing the ideas are provided in the appendix III of this thesis). Authors have included their own recommendations and ideas in long term implementation also in order to create a complete plan while considering issues within the whole supply chain of mechanical components. For the same reasons mentioned in previous section, the long term implementation plan is also provided in different tables.

Recommendation 1: decide agreements with the Chinese supplier

Identified Problems	Source
Lack of agreement and contract between two parties	• Simchi-Levi et al. (2008) mention that to ensure effective supplies and deliveries, and synchronize the supply chain, supply contracts should be agreed.

Recommendation 2: consider to integrate the control/IT system between parties involved which leads to implementing VMI

Identified Problems	Source
Lack of connections in control/IT systems within the supply chain.	• Skjott-Larsen (2007) mentions that new forms of enterprise in information system operations have developed significantly in order to manage the global supply chain activities. • This concept goes beyond the information sharing, the planning and control systems are integrated and coordinated through the supply chain. (Slack, 2006) • Jonsson & Mattsson (2009) indicate that the control system could be integrated by using *vendor-managed inventories (VMI)* or *customer-managed ordering (CMO).* • Brainstorming session (2016-04-29)

Recommendation 3: consider finding a backup supplier in Scandinavia for the mechanical component

Identified Problems	Source
Not considering the total costs of supplies.	• Skjott-Larsen (2007) mentions, "one objective of supply chain management is to reduce the total costs of product flow by eliminating this redundancy and integrating operations through close coordination. A second objective is to enhance the value of the final product by making the system, as a whole, more responsive to customer preferences" (p. 44). • Toovey (2000) indicates "the cost of maintaining inventory throughout the entire process is a hidden cost, but nevertheless becomes part of the product cost" (p. 1). • In order to ensure that the cost savings will bring profit for manufacturers; companies need to consider the inventory growth which is the outcome of choosing offshore suppliers. Purchasing from offshore suppliers makes it difficult for companies to implement a pull system; therefore manufacturing companies usually intend to purchase big batches (sometimes for one year consumption) and keep the material in stock (Dolcemascolo, 2006; Skjott-Larsen, 2007). It is important to consider and analyze the hidden costs of inventories such as; tied up capital and the costs related to occupying the floor space, when purchasing material from offshore suppliers. (Dolcemascolo, 2006; Jonsson, 2008).
Unable to have close coordination with the Chinese supplier.	• Communication barriers can cause delay and also create many other wastes in processes (Dolcemascolo, 2006). • In order to develop new customized products, companies need to interact with stakeholders involved in the supply chain. In these types of production environments, companies need to analyze customer specifications and also consider supplier capacity for implementing desired changes in design and engineering of the products. (Willner et al. 2014; Mello et al. 2015). • Gaps in material or information flow, create markable fluctuations in supplier side. The bullwhip effect can cause major problems such as exaggerated inventory investment, high level of safety stock, misguided production plans, wrong transport choice and poor customer service. (Moll, 2013; Slack, 2006). • It is significant to communicate frequently between supplier and customer about change in plans, material movements, stock levels and other sales strategies. Both parties should align the material planning in order to synchronize the material flow. This

	concept goes beyond the information sharing, the planning and control systems are integrated and coordinated through the supply chain. (Slack, 2006).

6 Conclusion

The main purpose of this thesis is to study the whole supply chain of one mechanical component from a Chinese supplier to the lighting company in Sweden in order to provide recommendations for adaptations in transportation mode, inventory management, demand management, and supply management. In order to identify the problems related to the supply chain and also provide recommendations for solving the problems; the information and material flow processes of the mechanical component were studied and investigated at the lighting company.

Three sub questions were formulated, in order to investigate the answer to the main research question. Each sub question is directed to one specific factor that have influence on the responsiveness of the supply chain.

Regarding to answering to the first sub question; (How do different transportation modes affect the cost and lead time of material flow?) the issues identified related to long transportation lead time, lighting company's attempt for using express air delivery during last year in order to prevent shortages and high costs of transportation due to weight of the mechanical components, were all taken into consideration. When providing recommendations for using the most suitable transportation mode, analysis and brainstorming session were considered for suggesting the sea transportation mode. It has been clear for authors that choosing the right transportation mode is a cost-lead time trade off. The value stream mapping has been a very useful tool for identifying the issues in information and material flow and also finding the improvement potentials. The value stream map clearly indicated long lead time and unbalanced inventory through the supply chain.

It was necessary to create the second sub question (What inventory level is appropriate to have sufficient goods for demand fluctuations?) in order to find a balance inventory level within the supply chain. Therefore, only focusing on choosing the right transportation mode is not sufficient for reducing the lead time of material flow and increasing the responsiveness in the supply chain. Answering to the second sub question, have guided authors to find an appropriate safety stock level in subcontractor site, Chinese supplier site and inside the lighting company. Analysis shown that predicting the safety stock can reduce the lead time of mechanical components from 90 days to 48 days. Furthermore, an appropriate reordering point and maximum inventory level have been calculated to ensure that the lighting company will be as responsive as possible to unpredictable customer demands.

Concerning unpredictable customer demands led to formulate a third sub question (How to reduce bullwhip effect by improving collaborations between different parties in the supply chain?). The existing bullwhip effect within the supply chain of mechanical components, as a result of uncertain forecasts and demand fluctuations from customer side, mostly affects the lighting company in Sweden. Moreover lack of safety stock for raw materials and mechanical components in the subcontractor site and the

Chinese supplier have increased the bullwhip effect. The answer to this question is related to improving collaborations between the Chinese supplier and the lighting company; and also creating information flow between the customer and the supplier. Contracts and agreements have decisive effect on reducing the bullwhip effect. Creating new conditions in the agreement can obligate the customer to provide better forecasts. Furthermore, contracts with the Chinese supplier for increasing the safety stock level and reducing the current prepayment terms (70%) increases a balance of risk sharing between the lighting company and the Chinese supplier which can reduce the bullwhip effect. Point of sale information also should be spread through the whole supply chain in order to increase the awareness of different parties about reasons behind the demand fluctuations.

Beside the challenges and Identified Problems mentioned above there are other areas of improvement which can be considered by the lighting company. A need for taking advantage of tools like material requirement planning (MRP) and vendor-managed inventory (VMI) have been identified in this thesis. However, the lighting company is using the MRP system to some extend; but the usage area for system needs to be improved. It has been considered by authors that implementing MRP and VMI as controlling IT systems which also connects the customer to the lighting company and the lighting company to the Chinese supplier belongs to long term implementation plan. This plan requires high investment and engagement from all the parties involved in the supply chain; therefore a simpler MRP has been recommended to the lighting company which can easily be understood and used by staff (appendix IV).

The main research question (RQ: How to make the supply chain of a customized product more responsive?) helped to identify many factors which can affect the responsiveness of supply chain for a customized product. Reducing the lead time for information and material flow within the supply chain of mechanical components, improving demand and supply relations and timely information sharing between different parties involved in the chain are among factors that have been identified during this thesis. It has been shown that additional information links must be created between the lighting company and the subcontractor and between the customer and the Chinese supplier. Moreover, current information flow between the lighting company and other parties within the supply chain needs to be improved also. Furthermore, authors found the importance of creating and signing the frameworks and contracts between the lighting company and its customer, and also between the lighting company and the Chinese supplier. Existence and specifics of contracts are necessary for implementation of changes which can improve the responsiveness of the supply chain. Responsiveness in supply chain lead to a high level of customer service level by keeping excess inventories through the supply chain and also to invest on aggressively reduce the lead time. Maintaining a safety stock at subcontractor site and doubling the capacity of the finished goods stock at Chinese supplier site have helped to reduce the lead time. However, the level of inventory at the lighting company in Sweden is below the maximum capacity due to inventory space constraints.

Several challenges faced by the lighting company today related to long lead time, inability to have face to face meeting with the Chinese supplier and high transportation costs can be tackled by finding a backup supplier located closer to the lighting company. However, costs of raw material and production provided by the Chinese supplier is much lower in compared to suppliers in Europe, but the lighting company must consider whether this cost saving will reduce the responsiveness of the supply chain.

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8 Appendix

I. Cost Calculation for Different Transportation Modes

- **Sea Transportation Cost**

SCAN by Sea (Door to Door 47 days)								
	Cost Type	**1 pallet**	**2 pallets**	**3 pallets**	**4 pallets**	**5 pallets**	**6 pallets**	**7 pallets**
Total import cost (without taxes)	Weight (W/M)	341.824	683.648	1025.472	1367.296	1709.12	2050.944	2392.768
Total truck cost (without taxes)	Forwarding	350	350	350	350	350	350	350
	Pick up (per 100 kgs) at least 495 SEK	170	480	840	1120	1400	1050	1225
	Terminal (W/M)	273	546	819	1092	1365	1638	1911
	Fee	210	210	210	210	210	210	210
	Custom	195	195	195	195	195	195	195
*USD rate 8.72	Total (SEK)	1864.824	2479.648	3439.472	4334.296	5229.12	5493.944	6283.768

- **Rail Transportation Cost**

SCAN by Rail (Door to Door 24-27 days)								
	Cost Type	**1 pallet**	**2 pallets**	**3 pallets**	**4 pallets**	**5 pallets**	**6 pallets**	**7 pallets**
Total import cost (without taxes)	Weight (W/M)	2197.44	4394.88	6592.32	8789.76	10987.2	13184.64	15382.08
Total truck cost (without taxes)	Forwarding	350	350	350	350	350	350	350
	Pick up (per 100 kgs) at least 920 SEK	1100	2500	2700	3600	4500	3750	4375
	Terminal (W/M)	147	294	441	588	735	882	1029
	DOC origin incl THC	2150	2150	2150	2150	2150	2150	2150
	Custom	600	600	600	600	600	600	600
*USD rate 8.72	Total (SEK)	6544.44	10288.88	12833.32	16077.76	19322.2	20916.64	23886.08

II. NL01 General Conditions

General Conditions NL 01 E

for the Supply of Machinery and other Mechanical, Electrical and Electronic Equipment

Issued in 2001 by the organisations for the engineering industries in Denmark, Finland, Norway and Sweden. (Hovedorganisationen Dansk Industri, Denmark; Metalliteollisuuden Keskusliitto, Finland; Teknologibedriftenes Landsforening, Norway; Sveriges Verkstadsindustrier, Sweden)

Preamble

1. These General Conditions shall apply when the parties agree in writing or otherwise thereto. Deviations from the Conditions shall not apply unless agreed in writing.

When used in these conditions the term "written" or "in writing" refers to a document signed by both parties or a letter, fax, electronic mail or other means agreed by the parties.

Product Information

2. Data in product information and price lists are binding only to the extent that they are expressly referred to in the contract.

Technical Documents and Technical Information

3. All drawings and other technical documents regarding the goods or their manufacture submitted by one party to the other, prior or subsequent to the formation of the contract, shall remain the property of the submitting party.

Drawings, technical documents or other technical information received by one party shall not, without the consent of the other party, be used for any other purpose than that for which they were submitted. They may not without the consent of the other party be copied, reproduced, transmitted or otherwise communicated to a third party.

4. The Seller shall, not later than by delivery of the goods, free of charge provide the Buyer with one copy, or the larger number of copies that may have been agreed, of drawings and other technical documents, which are sufficiently detailed to permit the Buyer to carry out installation, commissioning, operation and maintenance (including running repairs) of all parts of the goods. The Seller shall not, however, be obliged to supply manufacturing drawings of the goods or spare parts.

Delivery Test

5. Where a delivery test has been agreed, it shall, unless otherwise agreed, be carried out where the goods are manufactured. If technical requirements for the test have not been agreed, the test shall be carried out in accordance with general practice in the industry concerned in the country where the goods are manufactured.

6. The Seller shall notify the Buyer in writing of the delivery test in sufficient time to permit the Buyer to be present at the test. If the Buyer has received such notice, the test may be carried out even if the Buyer is not represented at the test.

The Seller shall record the test. The test report shall be sent to the Buyer. The report shall, unless otherwise shown by the Buyer, be considered to correctly describe the execution of the test and its results.

7. If at the delivery test the goods are found not to be in accordance with the contract, the Seller shall as soon as possible ensure that the goods comply with the contract. If so required by the Buyer a new test shall thereafter be carried out. The Buyer may not, however, require a new test if the defect was insignificant.

8. If no other division of the costs has been agreed, the Seller shall bear all costs for delivery tests carried out where the goods are manufactured. The Buyer shall, however, at such delivery tests bear all costs for his representatives, including costs for travel and subsistence.

Delivery

9. Where a trade term has been agreed, it shall be interpreted in accordance with the INCOTERMS in force at the formation of the contract.

If no trade term is specifically agreed, the delivery shall be Ex Works.

Time for Delivery. Delay

10. If, instead of a fixed date for delivery, the parties have agreed on a period of time within which delivery shall take place, such period shall start to run at the formation of the contract.

11. If the Seller finds that he will not be able to deliver the goods at the agreed time or if delay on his part seems likely, he shall without undue delay notify the Buyer thereof in writing, stating the reason for the delay and if possible the time when delivery can be expected. If the Seller fails to give such notice, he shall, regardless of the provisions of Clauses 13 and 14, reimburse the Buyer for any additional expenses, which the latter incurs and which he would have avoided, had he received notice in time.

12. If delay in delivery is caused by a circumstance which under Clause 36 constitutes ground for relief or by an act or omission on the part of the Buyer, including suspension by the Seller under Clause 18, the time for delivery shall be extended by a period, which is reasonable having regard to the circumstances in the case. The time for delivery shall be extended even if the reason for delay occurs after the originally agreed time for delivery.

13. If the Seller fails to deliver the goods on time, the Buyer is entitled to liquidated damages from the date on which delivery should have taken place.

The liquidated damages shall be payable at a rate of 0.5 per cent of the agreed price for each complete week of delay. If the delay concerns only a part of the goods, the liquidated damages shall be calculated on the part of the price which is properly attributable to the part of the goods which cannot be taken in use due to the delay.

The liquidated damages shall not exceed 7.5 per cent of that part of the price on which it is calculated.

The liquidated damages become due at the Buyer's written demand but not before all of the goods have been delivered or the contract is terminated under Clause 14.

The Buyer loses his right to liquidated damages if he has not lodged a written claim for such damages within six months after the time when delivery should have taken place.

14. If the Buyer is entitled to maximum liquidated damages under Clause 13, and the goods are still not delivered, the Buyer may in writing demand delivery within a final reasonable period which shall not be less than one week.

If the Seller fails to deliver within such final period and this is not due to any circumstance for which the Buyer is responsible, the Buyer may, by written notice to the Seller, terminate the contract in respect of that part of the goods which cannot be taken in use due to the delay.

In case of such termination the Buyer shall also be entitled to compensation for the loss he suffers because of the Seller's delay to the extent that the loss exceeds the maximum of liquidated damages which the Buyer may claim under Clause 13. This compensation shall not exceed 7.5 per cent of that part of the price which is properly attributable to the part of the goods in respect of which the contract is terminated.

The Buyer shall also have the right to terminate the contract by written notice to the Seller if it is clear that there will be a delay, which under Clause 13 would entitle the Buyer to maximum liquidated damages. In case of termination on this ground the Buyer shall be entitled to both maximum liquidated damages and compensation under the third paragraph of this Clause.

Except for liquidated damages under Clause 13 and termination of the contract with limited compensation under this Clause 14, all other claims in respect of the Seller's delay shall be excluded. This limitation of the Seller's liability shall not apply, however, where the Seller has been guilty of gross negligence.

15. If the Buyer finds that he will be unable to accept delivery of the goods on the agreed date, or if delay on his part seems likely, he shall without undue delay notify the Seller thereof in writing stating the reason for the delay and, if possible, the time when he will be able to accept delivery.

If the Buyer fails to accept delivery on the agreed date, he shall nevertheless make any payment which is dependent on delivery as if the goods in question had been delivered. The Seller shall arrange storage of the goods at the Buyer's risk and expense. If the Buyer so requires, the Seller shall insure the goods at the Buyer's expense.

16. Unless the Buyer's failure to accept delivery as referred to in Clause 15 is due to any such circumstance as described in Clause 36, the Seller may by written notice require the Buyer to accept delivery within a reasonable period.

If, for any reason for which the Seller is not responsible, the Buyer fails to accept delivery within such period, the Seller may, by written notice to the Buyer, terminate the contract in respect of that part of the goods which is ready for delivery but has not been delivered due to the Buyer's default. The Seller shall then be entitled to compensation for the loss he has suffered by reason of the Buyer's default. The compensation shall not exceed that part of the price which is properly attributable to the part of the goods in respect of which the contract is terminated.

Payment

17. Unless otherwise agreed, the agreed purchase price, together with value added tax, if any, shall be invoiced with one third at the formation of the contract, one third when the Seller gives written notice that the bulk of the goods are ready for delivery. Final payment shall be invoiced at delivery of the goods.

The invoiced amount becomes due 30 days after the date of the invoice.

18. If the Buyer fails to pay, the Seller shall be entitled to interest from the due date at the rate of interest determined by the law on late payments in the Seller's country.

If the Buyer fails to pay by the due date, the Seller shall also, after having notified the Buyer in writing thereof, suspend performance of his contractual obligations until payment is made.

19. If the Buyer has failed to pay the amount due within three months after the due date, the Seller may terminate the contract by written notice to the Buyer and, in addition to interest on late payment, claim compensation for the loss he has suffered. The compensation shall not exceed the agreed purchase price.

Retention of Title

20. The goods shall remain the property of the Seller until paid for in full, to the extent that such retention of title is valid.

Liability for Defects

21. The Seller shall, in accordance with the provisions of Clauses 23–33 below, remedy any defect in the goods resulting from faulty design, materials or workmanship.

The Seller is not liable for defects arising out of material provided by the Buyer or a design stipulated or specified by him.

22. The Seller's liability does not cover defects caused by circumstances, which arise after the risk has passed to the Buyer. The liability does not, for example, cover defects due to conditions of operation deviating from those anticipated in the contract or to improper use of the goods. Nor does it cover defects due to faulty maintenance or incorrect installation from the Buyer's side, alterations undertaken without the Seller's written consent or faulty repairs by the Buyer. Finally the liability does not cover normal wear and tear or deterioration.

23. The Seller's liability is limited to defects which appear within a period of one year from the date of delivery of the goods. If the goods are used more intensely than agreed, this period shall be reduced proportionately.

24. For parts, which have been repaired or replaced under Clause 21, the Seller shall have the same liability for defects as for the original goods for a period of one year. For other parts of the goods the liability period referred to in Clause 23 shall be extended only by the period during which the goods could not be used due to a defect for which the Seller is liable.

25. The Buyer shall notify the Seller in writing of a defect without undue delay after the defect has appeared and in no case later than two weeks after the expiry of the liability period defined in Clause 23 as supplemented by Clause 24. The notice shall contain a description of how the defect manifests itself. If the Buyer fails to notify the Seller in writing within the above time limits, he loses his right to make any claim in respect of the defect.

If there is reason to believe that the defect may cause damage, notice shall be given forthwith. If notice is not given forthwith, the Buyer loses the right to make any claim based on damage which occurs and which could have been avoided if such notice had been given.

26. After receipt of a written notice under Clause 25, the Seller shall remedy the defect without undue delay. Within this limit the time for remedial work shall be chosen in order not to interfere unnecessarily with the Buyer's activities. The Seller shall bear the costs as specified in Clauses 21–32.

Remedial work shall be carried out at the Buyer's premises unless the Seller finds it appropriate to have the defective part or the goods sent to him for repair or replacement at his own premises.

The Seller shall carry out dismantling and re-installation of the part if this requires special knowledge. If such special knowledge is not required, the Seller has fulfilled his obligations in respect of the defect when he delivers a duly repaired or replaced part to the Buyer.

27. If the Buyer gives such notice as referred to in Clause 25, and no defect is found for which the Seller is liable, the Seller shall be entitled to compensation for the work and costs which he has incurred as a result of the notice.

28. If remedy of the defect requires intervention in other equipment than the goods, the Buyer shall be responsible for any work or costs caused thereby.

29. All transports in connection with repair or replacement shall be at the Seller's risk and expense.

The Buyer shall follow the Seller's instructions regarding how the transport shall be carried out.

30. The Buyer shall bear the increase in costs for remedying a defect which the Seller incurs when the goods are located elsewhere than at the destination stated in the contract or – if no destination has been stated – the place of delivery.

31. Defective parts, which have been replaced under Clause 21, shall be placed at the Seller's disposal and shall become his property.

32. If the Seller fails to fulfil his obligations under Clause 26 within a reasonable time, the Buyer may by written notice require him to do so within a final time. If the Seller fails to fulfil his obligations within that time limit, the Buyer may at his option:

a) have the necessary remedial work carried out and/or have new parts manufactured at the Seller's risk and expense, provided that the Buyer proceeds in a reasonable manner, or

b) demand a reduction of the agreed purchase price not exceeding 15 per cent thereof.

If the defect is substantial, the Buyer may instead terminate the contract by written notice to the Seller. The Buyer shall also be entitled to such termination where the defect remains substantial after measures referred to in a). In case of termination, the Buyer shall be entitled to compensation for the loss he has suffered. The compensation shall not, however, exceed 15 per cent of the agreed purchase price.

33. Regardless of the provisions of Clauses 21–32, the Seller shall have no liability for defects in any part of the goods for more than two years from the start of the liability period referred to in Clause 23.

34. The Seller shall have no liability for defects save as stipulated in Clauses 21–33. This applies to any loss the defect may cause, such as loss of production, loss of profit and other consequential economic loss. This limitation of the Seller's liability shall not apply, however, if he has been guilty of gross negligence.

Liability for Damage to Property Caused by the Goods

35. The Buyer shall indemnify and hold the Seller harmless to the extent that the Seller incurs liability towards any third party in respect of loss or damage for which the Seller is not liable towards the Buyer according to the second and third paragraphs of this Clause.

The Seller shall have no liability for damage caused by the goods:

a) to any (movable or immovable) property, or consequential loss due to such damage, occurring while the goods are in the Buyer's possession, or

b) to products manufactured by the Buyer or to products of which the Buyer's products form a part.

The above limitations of the Seller's liability shall not apply if he has been guilty of gross negligence.

If a third party lodges a claim for compensation against Seller or Buyer for loss or damage referred to in this Clause, the other party to the contract shall forthwith be notified thereof in writing.

The Seller and the Buyer shall be mutually obliged to let themselves be summoned to the court or arbitral tribunal which examines claims against either of them based on damage or loss alleged to have been caused by the goods. The liability as between the Seller and the Buyer shall, however, always be settled by arbitration in accordance with Clause 39.

Grounds for Relief (Force Majeure)

36. The following circumstances shall constitute grounds for relief if they impede the performance of the contract or makes performance unreasonably onerous: industrial disputes and any other circumstance beyond the control of the parties, such as fire, war, mobilization or military call up of a comparable scope, requisition, seizure, trade and currency restrictions, insurrection and civil commotion, shortage of transport, general shortage of materials, restrictions in the supply of power and defects or delays in deliveries by sub-contractors caused by any such circumstance as referred to in this Clause.

The above described circumstances shall constitute grounds for relief only if their effect on the performance of the contract could not be foreseen at the time of formation of the contract.

37. The party wishing to claim relief under Clause 36 shall without delay notify the other party in writing on the intervention and on the cessation of such circumstance.

If grounds for relief prevent the Buyer from fulfilling his obligations, he shall reimburse the expenses incurred by the seller in securing and protecting the goods.

38. Notwithstanding other provisions of these General Conditions, either party shall be entitled to terminate the contract by notice in writing to the other party, if performance of the contract is delayed more than six months by reason of any grounds for relief as described in Clause 36.

Disputes. Applicable Law

39. Disputes arising out of or in connection with the contract shall not be brought before the court, but shall be finally settled by arbitration in accordance with the law on arbitration applicable in the Seller's country.

40. All disputes arising out of the contract shall be judged according to the law of the Seller's country.

Rollco AB, http://rollco.se/uk/wp-content/uploads/2012/11/NL01-English.pdf (2016-04-14)

III. Brainstorming Session

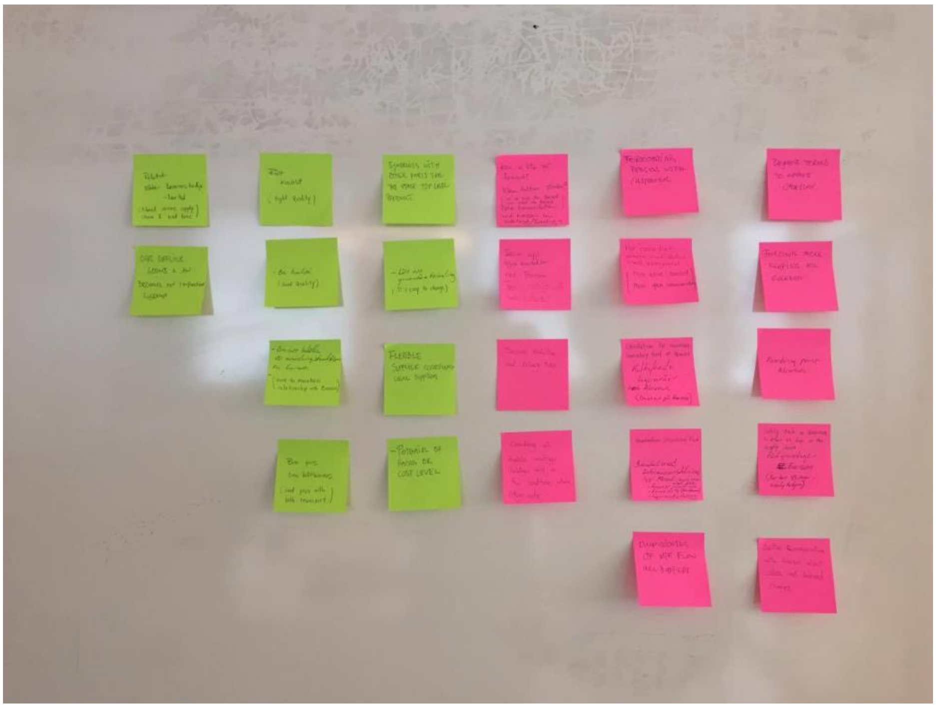

Figure 19 Combined all ideas.

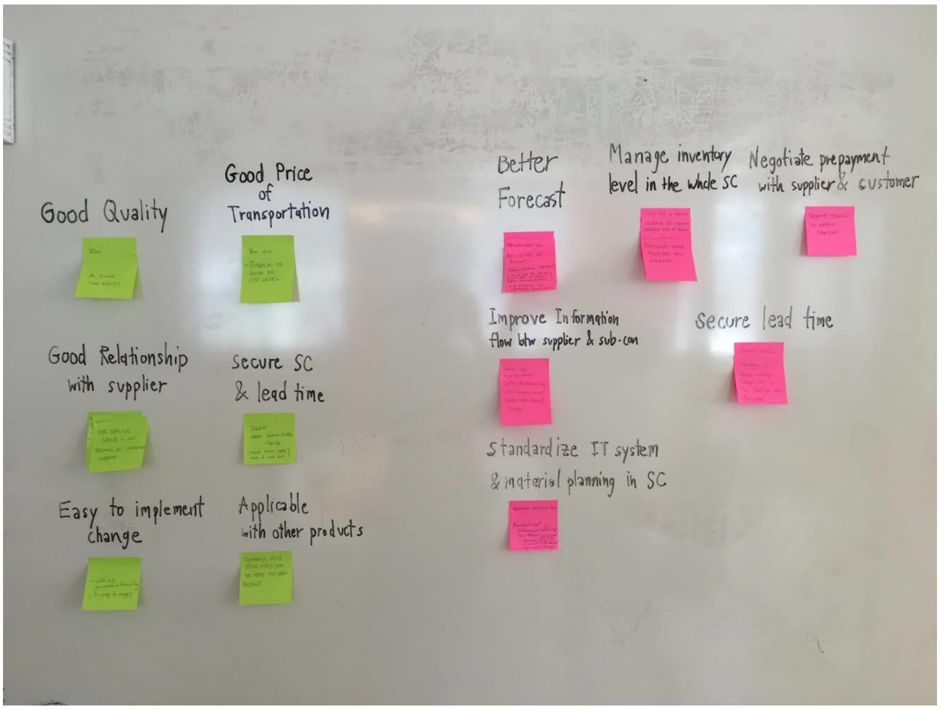

Figure 20 Combined similar ideas into one and set the topic.

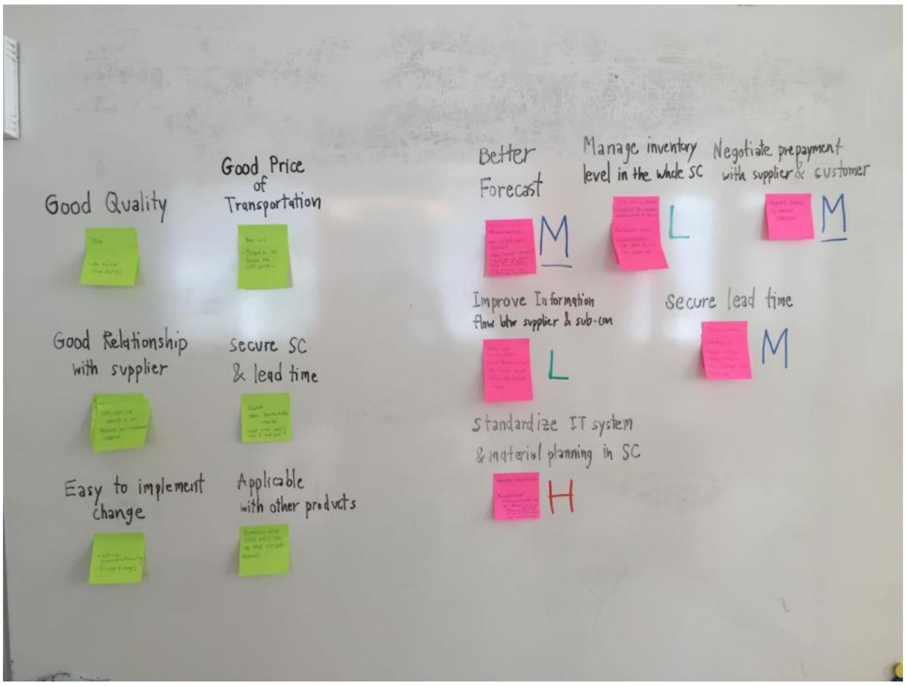

Figure 21 Categorized each topic into short term and long term implementation plans.

IV. Suggestion for ROP and MRP Calculation

According to the analysis, the most suitable method for estimating an inventory level and reorder point for the mechanical components is to base the calculation on customer forecasts. This section shows the reordering point, inventory level and material planning for the mechanical component based on the 5000 pcs demand forecast for Sunny product in 2016. Two choices have been studied and calculated by authors in order to secure the inventory of mechanical components.

<u>*Choice One*</u>

First choice is to predict a SS level and maximum inventory level for mechanical components. Due to unpredictable demand and lack of order history for Sunny products; authors have decided to base calculations on 5000 forecast for 2016 (Number of working days/week in China, Sweden and during the shipping time differ from each other; for instance 6 working days each week have been considered for China, 7 working days per week have been considered for boat transportation and 5 working days per week have been considered for the lighting company in Sweden).

Demand forecast = 5000 pcs
Lead time according to the VSM = 90 days = 12.8 weeks ≃13 weeks ≃65 working days
Working days per year = 245 day (5 days/week)
Demand per day = 5000 pcs/ 245 days = 20.4 pcs/day ≃21 pcs/day

The Chinese supplier keep 1000 pcs of mechanical parts in their SS then according to FSM the lead time can be decreased;

(90 *days* - 43 *production days*) + 1 day waiting for truck = 48 days ≃7 weeks
Replenishment cycle stock = 48 x 21 = 1008 pcs

SS for mechanical components has been calculated for three weeks consumption. Level of SS has been estimated by considering 7 weeks lead time (the SS covers the production for almost half of the lead time).

SS = Three weeks consumption = 3 x 5 x 21 = 315 pcs
Max inventory level = 315 + 1008 = 1323 pcs

Then the reorder point will be;

ROP = SS + (D x L) = 315 + (21 x 5 x 7) = 1050 pcs

Calculations indicate that a new order must be placed when the inventory level reach 1050 pieces, furthermore they indicate the order size of 1008 pieces while 315 pieces are kept in the SS. The purchasing order size from Chinese supplier can be fixed to

1000 pieces. When ordering 1000 pieces the lead time will include production time at Chinese supplier, and it will be around 90 days. The cause of this long lead time is low level of finished goods SS at the Chinese supplier (500 pieces). If the Chinese supplier increase the level of SS from 500 pieces (around 4 pallets) to 1000 pieces (around 7 pallets) there will be a balance in material flow, and supplier will be more capable in fulfilling the customer's demand with short lead time.

Purchasing a batch size of 1000 pieces will be more profitable for the lighting company also, while it reduces the number of transportations from China to Sweden, and also prevents shortages in production.

Following choice describe two different material planning considering 500 pieces and 1000 pieces in batch size, the differences in transportation costs and number of orders will be discussed in the section also.

Choice Two

In the second choice, material requirement planning method is used to identify the suitable time to reorder mechanical parts. Data in the forecast row is based on monthly forecast from customer that was provided to the lighting company during weekly meeting. However, real forecasts in quarter 3 and 4 is stated in group; Q3 = 1450 and Q4 = 820. Therefore, authors have decided to split them out to 500-500-450 in month 7-8-9 and 300-300-220 in month 10-11-12.

There are some conditions which have to be followed in order to use this MRP method:

1. Chinese supplier always has 500 pieces of mechanical parts in their stock.
2. The company always has at least 1000 pieces of mechanical parts in their stock at the end of each year. Maximum stock level at the company for mechanical components is 1500 pieces.
3. Planned order must be sent to the Chinese supplier at the first week of ordering months. If there is delayed in sending order, it will affect the total lead time.
4. Lead time is 7 weeks for sea transportation and maximum capacity of production is 40 pieces per day at the company.
5. Stock on hand in month (X) is always more than forecast of next month (X+1) in order to avoid the shortage and using air transportation.
6. Net requirement is always 0.
7. If the order will be sent continuously, for example, the company orders in January and order in February again, the company has to inform the Chinese supplier in advance. Because the whole production process takes 37-43 days or around 7 weeks (6 working days at Chinese supplier), in the case that there is no aluminum in stock at the subcontractor.
8. In real situation, authors understand that there is high risk for changes in forecasts, therefore, the company must secure the forecasts at least for upcoming 8 weeks in order to use this method.

Table 6. Illustration of Material Requirements Planning of Mechanical Part for 2016 (500).

Time Period (Month)		1	2	3	4	5	6	7	8	9	10	11	12
Forecast		20	30	1000	500	440	430	500	500	450	300	300	220
Stock on hand	1000	980	1450	950	450	510	580	580	580	630	330	530	310
Net requirement		0	0	0	0	0	0	0	0	0	0	0	0
Planned delivery			500	500		500	500	500	500	500		500	
Planned order start		500	500		500	500	500	500	500		500		

As it is shown in table 5, there are 8 planned deliveries in one year which means that the total sea transportation cost will be equal to (see transportation cost in table 4);

$4334.3 \times 8 = 34\ 674.4$ SEK (4 pallets)

Therefore, if the lighting company can change to order a batch size of 1000 pieces in each time, the deliveries will reduce to 4 times per year and the transportation cost will be equal to;

$6283.77 \times 4 = 25\ 135.08$ SEK (7 pallets)

Calculations indicate that the lighting company can save approximately 9 539.32 SEK by shipping a batch size of 1000 pieces (7 pallets) four times a year;

34 674.4 SEK − 25 135.08 SEK = 9 539.32 SEK

However, there are some consequences which the company should consider also:

1. Chinese supplier always must keep 1000 pieces of mechanical parts in their SS.
2. Ordering a batch size of 1000 pieces can affect the cash flow of the company due to the high prepayment term (70%) decided by the supplier. In order to implement this recommendation the company and the supplier should negotiate and reduce the percent of the prepayment.
3. Other conditions are the same with the 500 pieces batch size.
4. In month 3, net requirement is equal to 50 which is very small amount when comparing to the 1000 pieces batch size. Therefore, authors decide to not increase the order batch size for this month. In this case the company should make decisions based on their own profit.

Table 7. Illustration of Material Requirements Planning of Mechanical Part for 2016 (1000).

Time Period (Month)		1	2	3	4	5	6	7	8	9	10	11	12
Forecast		20	30	1000	500	440	430	500	500	450	300	300	220
Stock on hand	1000	980	950	950	450	1010	580	1080	580	1130	830	530	310
Net requirement		0	0	50	0	0	0	0	0	0	0	0	0
Planned delivery				1000		1000		1000		1000			
Planned order start			1000		1000		1000		1000				

<u>*Comparison between two choices*</u>

As mentioned before, the inventory of mechanical components needs to be balanced through the whole supply chain, in order to secure the lead time to customer, prevent shortages and increase the responsiveness of the supply chain. In order to create this balance, the lighting company can choose a combination of ROP with material planning for order batch size of 500 pieces or ROP with material planning for order batch size of 1000 pieces. For instance the lighting company can choose to order 500 pieces, 8 times per year when the inventory level reaches 1000 pieces; or order a batch size of 1000 pieces less frequent (4 times per year).

However as discussed before ordering 1000 pieces of mechanical components can reduce the transportation cost, have negative effect on the cash flow (if the prepayment term maintain 70%) and increase the tied up capital in the lighting company and inventory cost at the Chinese supplier site. But this is also the best choice for securing the lead time of orders and also securing the inventory at the lighting company.

For the choice 1 (ROP), the advantage in the view of authors is that the method is easy for the lighting company to manage because there is no need to check the forecast and replan the MRP. The lighting company only check the inventory of mechanical part in the stock and put order to the Chinese supplier when the stock reduces to 1000 pieces. However, if there is no purchasing order from customer in two months, after the lighting company receives new delivery, there is a chance of over maximum stock capacity (1500 pieces) in the warehouse. It indicates that securing the customer forecasts is necessary for this case also.

For the choice 2 (MRP), according to uncertain forecast from customer the lighting company cannot implement the IT system perfectly in order to plan material requirement. Therefore, the lighting company has to create manual MRP which requires human resource and time. However, the good point is MRP can ensure that the lighting company will not face over stock situation.

V. Questionnaire

Financial Questions

1. What is the cost of the transportation for air transport, boat and train?

2. How often do the company meet the Chinese suppliers and how much the company invest on these meetings?
3. How much is the administration cost for putting orders?
4. How much interest rate does the company pay? (Pay back to the bank 1 year or half a year?)
5. How much is the unit cost of the product?
6. How much is unit cost for mechanical component?

General Product Questions

1. Where the CODP locate in the product structure?
2. Does the supplier have MTO or MTS environment?
3. Does the supplier produce the component only for your company or it is included in their original products?
4. Have you ever searched for others supplier before choosing this supplier?
5. Do you use the critical component in other products beside Sunny product?
6. What is the purchase quantity based on? (container size, minimum production requirement, discount price for unit)

Questions about the Chinese Supplier

1. Does the company, keep any SS for the components delivered from the Chinese supplier?
2. Do you send both forecast and actual order to the supplier?
3. How often did you send the order to the supplier (which month during the year)?
4. What criteria did you consider for choosing the supplier?
5. Do you have any contact person in China who visits the supplier company?
6. How often do you visit the supplier company in China?
7. How the size of the supplier company in is compared to your company?
8. Do you use any IT system to connect with suppliers?
9. Do you collaborate with the supplier in order to develop the components?
10. Do you have any statistics which shows the rate of scraps in each order?
11. How do you send quality feedbacks to the supplier?
12. Do the supplier offer any special discounts, when some errors have been identified in the order?
13. Have you searched for other supplier alternatives?
14. Which kind of contract the company has signed with the supplier? (Identify volume, price, lead time, quality, return policy, long-term…)
15. Does the supplier pay penalty for late delivery?
16. Did your company collaborate with the Chinese supplier before producing Sunny products?
17. Is your company interested in considering some frameworks for the Chinese supplier and/or sign agreement?

Inventory and Demand Management Questions

1. What is the maximum inventory capacity for the mechanical components (SS + Replenishment cycle stock)?

2. What is the actual daily demand for mechanical components?
3. We know that the company is keeping finished goods inventory for the customer. Do you think this is considered as profit/income for the company?
4. How much does the customer pay for stock keeping? Is it based on amount pallets or number of shelves they occupy?
5. What is the inventory cost for keeping one pallet of raw material?
6. Do you consider any buffer stock for mechanical components?
7. How much do you think the safety factor percentage can be (this percentage is based on supplier's quality, reliability and delivery time); for considering the SS?
8. Are there any agreements regarding to the maximum number of finished goods the company keeps for the customer?
9. Do you think limiting the number of finished goods in the inventory can increase the capacity for keeping more raw material?
10. Which factor do you think can suit the inventory strategies of the company better when deciding the reordering point; to consider a time frame (for example order quarterly) or to consider the customer forecasts and daily demand?

Transportation and Shipment Questions

1. Can you clarify the payment for boat, train and air transport? Does the payment occur after the receiving the good?
2. Does the company pay for transport from the supplier company to the airport, for shipping by air?
3. Can we have the ordering history for mechanical components?
4. What is the cost for transportation from airport to to the company in Sweden?
5. Do you get any discounts from logistics partners? What are the discounts based on?
6. Does the Chinese suppliers ship only the components for chosen product family or they also ship for other products in the company?
7. Who pay expense from supplier factory to the harbor?
8. Which components are usually shipped by air?
9. How often do you get delivery from the supplier?

Questions about the Customer

1. How long have you worked with this customer?
2. In what industry the product is used?

3. Can we public the product name? What about the company name and the supplier name?
4. How is the size of customer company compared to the lighting company?
5. Is the customer the end customer or retailer?
6. Which kind of contract do you use with customer?
7. How often did you receive the forecast and order from the customer during 2014 and 2015?
8. Do you know about the forecast method that they used?
9. How often the customer require order delivery? (which month)
10. How do you see the future of this customer?
11. What is the prepayment agreement with the customer?
12. How many purchasing orders do you have from the customer today?
13. When do you think the company is going to sign ordering and forecast agreements with the customer?
14. What is the IT system that the customer company is using today?
15. Do you think the company will have the possibility to have common IT system with the customer company in future?
16. Does the customer company share information about their sales plan or information which can affect the demand?

Questions about Customer Forecasts

1. Who receive the customer forecast?
2. What was the forecasts for 2014, 2015 and 2016?
3. Which kind of contract do you have with the supplier?
4. What is the purchase quantity based on? (container size, minimum production requirement)
5. How often the customer put actual order during last year?
6. After receiving the order from the customer, how long does it take for you to feed it into MRP system?
7. After receiving the order from the customer, what is the process you do before sending purchasing order to Chinese supplier?
8. How many mechanical components do you usually keep in stock? Do you calculate safety stock for this part? (Or reordering point)
9. How many LED lamps do you usually deliver to finish goods stock? Do you have any batch size or the amount of delivered lamps depend on (the customer order or the capacity of carrying carriage)?

Value Stream Map Questions

1. How often the customer put the forecasts during last year?
2. How often the customer put actual order during last year?

3. Who gets forecast & order from the customer?
4. Tell us about the relationship between the company and the Chinese supplier?
5. What are the criteria for supplier selection?
6. How long does it take from getting the actual orders until feeding them into MRP system?
7. After feeding in the MRP system, do you directly start production?
8. Does the Chinese supplier have MRP system?
9. What was the shipping batch by boat and train from the Chinese supplier to the company in last year?
10. Have you ever send the mechanical components by plane during the last year? How many times?
11. How long time does it take from when the company receive customer order until you start PCB production?
12. What is PCB batch size for selected product?
13. How long does it take from when one MCB is ready in SMD lines until you start final assembly?
14. How do you distribute the production plan for selected product in one week?
15. Does the company report defects to the Chinese supplier? How many?
16. How many hour per day the production site operated? (excluding lunch and breaks)
17. How many shifts?

Questions for the Chinese Supplier

<u>General</u>

1. Can you explain briefly about the flow of mechanical components' production in subcontractor company and inside your company?

<u>Information Flow</u>

1. What IT system do you use to support the material and information flow (MRP)?
2. After receiving the order from Sweden, how long does it take for you to feed it in your IT system?
3. After receiving the order from Sweden, do you report the order immediately to subcontractor? If not, how long does it take?
4. Which method do you use for sending order to your subcontractor? (call/email/IT system)
5. What IT system do your subcontractor use to support the material and information flow (MRP)?
6. How long does it take for subcontractor to confirm the order?
7. How often do you send order to the subcontractor company? (regarding to producing the mechanical components)

<u>Material Flow</u>

1. How far (in km) is the distance between your company and Qingdao harbor?
2. How far (in km) is the distance between your company and train station?
3. How far (in km) is the distance between your company and the subcontractor?
4. How far (in km) is the distance between the subcontractor and the aluminum supplier?
5. How long time does it take from when the aluminum supplier receives the order until they are ready to ship it to the subcontractor? (queue time)
6. What is the transportation time between aluminum supplier company to the subcontractor company? By truck?
7. Does the subcontractor keep finished goods in stock before send to you? If yes, how long time they usually keep them?
8. How long time does it take from when the subcontractor has the shipping order ready until the truck comes to pick up the mechanical components for send it to your company?
9. What is the transportation time between the subcontractor company to your company? By truck?
10. How long time does it take from when you receive the mechanical components from subcontractor until the goods are ready to ship?
11. Does your company keep some finished goods (mechanical component) in stock or you send them all to Sweden?
12. What is the shipping batch for the mechanical components? What is the factor that you use to set the shipping batch?
13. How long time does it take from when you has the shipping order ready until the truck comes to pick up the mechanical components?
14. What is the transportation time between your company to the harbor in Qingdao? By truck?
15. What is the transportation time between your company to the train station in Qingdao? By truck?

About Production in Supplier Company

1. Regarding to production of mechanical components;
    - What is the queue time before you can start producing the mechanical components?
    - What is the batch size?
    - What is the production time for one batch size?
2. What is the defect rate of the mechanical components production at your company?
3. About production hours at your company, how many shifts do you work? How many hours/day? And how many days/year?
4. How often do you need to build up stock for mechanical parts?
5. What is the production time of mechanical parts for a) a batch size of 1000 pieces and b) a batch size of 1500 pieces?

About Production in Sub-contractor Company

1. What is the queue time before subcontractor can start producing the mechanical components?
2. What is the batch size of the mechanical components that the subcontractor usually produces?
3. What is the production time for one batch size of the mechanical component?
4. What is the defect rate of the mechanical components production at the subcontractor company?
5. About production hours at the subcontractor company, how many shifts do they work? How many hours/day? And how many days/year?
6. What is the production time of mechanical parts for a) a batch size of 1500 pieces and b) a batch size of 2000 pieces?

Questions for SCAN logistics company

1. What is the queue time that mechanical components have to wait at the harbour before they are shipped?
2. What is the queue time that mechanical components have to wait at the train station before they are shipped?
3. What is the queue time that the mechanical components have to wait in Gothenburg train station until they are shipped to the lighting company?
4. How do you calculate W/M for boat transport from Qingdao to Göteborg?
5. About local transport in Sweden for instance from harbor in Göteborg to the company; how do you calculate the pickup cost? What is the price based on?
6. How do you calculate the terminal cost?
7. Is the queue time in the Chinese harbor included in 40 days delivery from Qingdao?
8. How long is the transportation time between Qingdao train station to Gothenburg train station?