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DEVELOPMENT OF SPARE PART BUSINESS PROCESS AT A TECHNOLOGY COMPANY

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TIIVISTELMÄ

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Varaosaliiketoimintaprosessin kehittäminen teknologiayrityksessä

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Tämän diplomityön tavoitteena oli selvittää kohdeyrityksen varaosaliiketoiminnan arvoketjun suurimmat ongelmakohdat. Samalla tavoitteena oli kehittää ratkaisuja löydettyihin ongelmiin, etenkin alueille, joihin asiakkaat olivat tyytymättömiä. Lopputyö tehtiin tapaustutkimuksena kohdeyritykseen käyttäen sekä kvantitatiivisia että kvalitatiivisia tutkimusmenetelmiä. Käytetyt kvalitatiiviset metodit olivat kirjallisuustutkimus ja puolistrukturoidut sekä strukturoimattomat haastattelut. Pääasiallisena kvantitatiivisena metodina käytettiin tilastollista tutkimusta.

Tilaus-toimitusketjun nykytilaa analysoitiin numeerisesti läpimenoaikojen sekä keskeneräisen tuotannon avulla eri osastoilla ja paikkakunnilla. Datan pohjalta koottiin arvovirtakuvaus, joka esittää työvaiheiden väliset yhteydet ja asiakkaan kokeman läpimenoajan. Läpimenoajan ja keskeneräisen tuotannon keskiarvo sekä vaihtelu olivat suurinta tarjouspyyntöprosessissa. Tämä indikoi, että systeemin pullonkaula löytyy myynnin alueelta ja jonne kehityspanokset tulisivat suuntautua.

Myyntiorganisaatiolle tehdyistä haastatteluista kävi ilmi syitä pitkiin ja vaihteleviin läpimenoaikoihin, joista merkittävimpänä tuotetiedonhallinnan tila. Analyysi SPC-kuvaajien avulla todisti, että asiakkaat eivät saa ennustettavaa palvelua myyntiorganisaatiosta, ja vasteajoissa ilmenee suurta vaihtelua. Lisäksi yrityksen sisäiselle toimitusprosessille ei varattu riittävästi aikaa ja siinä havaittiin tarpeetonta viivettä lähtevän tavaran kuittaamisessa.

Myyntiorganisaatiolle annettiin suositus toimitusprosessille varattavasta ajasta, sekä tavasta kuitata lähtevä tavara. Lisäksi ehdotettiin jatkuvan kehityksen metodia, jolla stabiloida prosessia. Tämä muodostuu SPC-kuvaajien hyödyntämisestä vaihtelua aiheuttavien, määritettävissä olevien syiden tunnistamiseen. Tämän lisäksi ehdotettiin konseptia uudesta tavasta organisoida ja priorisoida myyntiin tulevat tehtävät. Annettuja ehdotuksia on tarkoitus kokeilla käytännössä lopputyön jälkeen.

ABSTRACT

LUT University
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Development of spare part business process at a technology company

Master's thesis

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69 pages, 18 figures, 1 tables and 3 appendices

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The objective of this thesis was to find out the most significant problems along the value stream of a case company's spare part business. Against the found problems, alleviating concrete solutions were to be developed to improve areas, which customers found dissatisfying. The thesis was done as a case study while using both quantitative and qualitative methods. Qualitative methods consisted of unstructured interviews and a literature review, the main quantitative method utilized was statistical research.

The current state of the order-to-delivery chain was analyzed numerically based on lead-times and the amount of work-in-progress in different operations and locations. The value stream map was constructed based on the data, presenting the connections between work phases and the total performance of the system. Average lead-times and amount work-in-progress was highest in the quotation process. This indicated that the bottleneck of the system could be found in the sales department. Further development was focused there.

Based on the interviews made to the sales department, multiple causes to long lead-times were obtained, the most significant being problems in the state of product data management. Detailed analysis with SPC-charts proved that the customers are not receiving predictable service from the sales department and large variation on response-times occurs. From the inner delivery process of the case company, unnecessary delays and disproportions on the time reserved to it were found.

For the sales department, suggestion on how much time should be reserved for the rest of the value chain was given. In this context, a recommendation to increase the pace of ready for delivery –booking was given. Method for stabilizing the processes via continuous development was suggested. This contains utilizing of SPC-charts to detect assignable causes behind long lead-times. In addition, a new way of organizing and prioritizing the incoming tasks was presented. Ideas presented are to be tested in the case company after the completion of the thesis.

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I would like to thank the case company for offering such an interesting topic for the thesis. I hope that this work can be utilized along the road of improvements. In addition, I would like to express my gratitude for both, Satu Svensson and Juha Varis for guiding me through this process. Your advice was priceless for the completion of this thesis. Greatest of thanks goes to the persons I got to interview during the process. You spent your valuable time and interest to teach me and answer my questions.

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Jyri Lakka
In Helsinki 20.6.2019

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LIST OF SYMBOLS AND ABBREVIATIONS

BOM	Bill of Materials
c_a	Coefficient of variation, arrival
c_e	Coefficient of variation, effective
CT	Lead-time
DAP	Delivery at place
DMS	Data management system
ERP	Enterprise resource planning
FCA	Free carrier
FIFO	First-in-first-out
KPI	Key performance indicator
LCL	Lower control limit
MTO	Make-to-order
p	Probability of error
PDCA	Plan-Do-Check-Act
PDM	Product data management
RFQ	Request for quotation
RTY	Rolled-throughput-yield
SPC	Statistical process control
t_e	Effective processing time
TH	Throughput
TOC	Theory of constraints
u	Utilization rate
U	Utilization rate coefficient
UCL	Upper control limit
V	Variation
VSM	Value stream mapping
WIP	Work-in-progress
5FS	Five focusing steps

1 INTRODUCTION

In this master's thesis, the value chain of a company that designs and manufactures mechanical equipment is studied. Research is focused on the spare part business of the company and its process from the customers' point of view. The study considers chain from the customer needing a spare part to the delivery of the desired part.

In the manufacturing industry, interest in offering different services has been on the rise in recent decades. As the customers are focusing more on their own core businesses, they require assistance to handle their support functions. This can offer great market potential and growth for service providers. The service in this context could be, for example, technical expertise on the usage of sold products, different maintenance services for equipment, identifying and selling the needed spare parts for the equipment. Services are also less sensitive to fluctuations of the markets than the traditional sales of new investment products. A customer buys machinery to make its products, it has to be kept operational with maintenance so, that the investment pays off. This offers potential business for the service provider. (Johansson & Olhager 2004, p. 309-310.)

1.1 Background and motivation

Due to the importance of service stated above, the speed of customer service and its quality should be more in the center point of focus. For any company, this could provide an essential way to stand out amongst the competition. In the end, the customer is only interested in the efficiency of the transaction between trade partners, not in the efficiency of the inner processes of the vendor. The customer wants; that his requirements are noticed and answered quickly, the product is delivered by the agreed date and agreed on quantity, according to the product specification and for an agreeable price. By doing this efficiently, a business can grow within its old customer base and try to grasp new customers. Operations should be so good, that customer wants to do business because the process starts immediately and customer needs are handled every time without interruptions. (Duggan 2012, p. 61.)

Eventually, the purpose of improvements in operations is to gain growth for the business. Business growth comes from increased market share and profits; gaining something in the bottom line. (Duggan 2012, p. 61.) In the case company, customers are purchasing expensive equipment for their production and they are promised of certain upkeep with spare parts. This promise is a precondition that equipment is purchased in the first place. If spare part service is not at the required level by the customer, they are not satisfied and in the worst-case, start to look for other options when purchasing new equipment.

The case company conducted a customer satisfaction survey during 2018, in which spare part business performance was observed. The areas customers found most challenging while doing business with the spare part organization of the case company are presented in figure 1. Out of 45 answers given in total, delivery times and response times to inquiries were mentioned in the answers as the two most challenging areas.

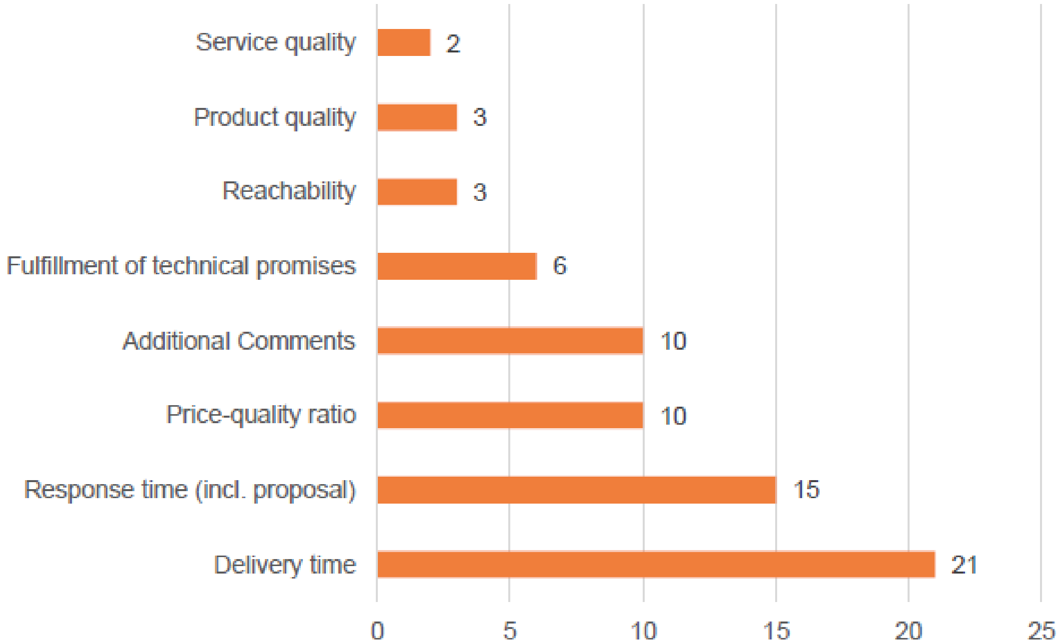

Figure 1. Customer satisfaction survey: “Which areas are most challenging in spare part business” (PBI Research Institute 2019, p. 15).

1.2 Research problem and the objective

As the customer survey presented above states, response and delivery time are the most troublesome areas of the case company’s business according to customers. These are also areas, which customer values greatly and properly done can provide a competitive advantage for a company. The research problem for this study is to recognize what causes customer dissatisfaction in the spare part business process. To guarantee an acceptable level of service, the objective of the thesis could be derived. It is to find out the most significant problems along the value stream and offer concrete solutions to alleviate the issues.

1.3 Research questions and hypothesis

To find answers to the research problem and eventually reach the objective, three research questions were formed. These are presented following:

- What is the current state of the case company's value chain?
- How the found problems could be solved or alleviated?
- Could the case company utilize lean methodology to achieve shorter lead-times within processes and how?

In this work, the hypothesis could be set as follows; currently, the response times and lead-time in the whole process is too long. If the current state is analyzed, and constraints of the system found and improvement suggestions made, the lead-times and response times could be decreased, if suggested actions are taken.

1.4 Scope

The scope of this study is in the case company's spare part business. More specifically, the value chain from the customer's quotation to the delivery of a required good is examined. As the case company is operating globally, this study is limited to focus only on the value streams of Finnish operations, consisting of three locations, A, B, and C. Study is limited for transactions, which are done by the spare part sales teams within the year 2018.

2 RESEARCH METHODS

The research is conducted by using both qualitative and quantitative research methods. This is ensuring that the research reaches its objective and is done in a scientific manner. Thus, it should produce additional value for the scientific community, concrete and novel information for the case company regarding the state of the spare part business. This knowledge should be analogical to other businesses in the related field of spare part sales and results could be utilized with some variation.

2.1 Qualitative methods

For qualitative analysis, a literature review is conducted, so basic knowledge is acquired from the field closely related to the study. The study is focusing on order-to-delivery chains and lean methodology in office. For information retrieval, Lappeenranta Academic Library and its databases are utilized with such keywords as value chain, order-to-delivery process, sales process, purchasing process, shipping process and lean in office. The focus is kept on scientific publications to ensure the reliability of the study.

In addition to the literature review, interviews are done for the key personnel of the company related to each area of the order-to-delivery process. With the help of these experts, the current state of the process is perceived as it is. Interviews are done mainly as unstructured, but with some guiding questions. Unstructured interviews are free discussions between various persons among the case company’s value stream, such as sales manager, sales engineer, purchasing manager, purchaser, and shipping manager. To gain knowledge from each area of business, short “basic training” from each was held for the author; similar to what could be done to new employees. During these trainings, previously determined questions were discussed to guide the conversations to points of interest, being the problem areas of the value chain.

2.2 Quantitative methods

To gain an objective point of view to the current state of spare part business, quantitative methods are utilized as well. This part of the study is done as statistical research. The case company is using SAP enterprise resource planning (ERP) software, in which various different data sets can be acquired. These include different time stamps from each individual process steps conducted by sales, purchasing, warehousing and shipping at a detail level. With this data, for example, lead-times and work-in-progress (WIP) inside the process can be analyzed. Data is analyzed utilizing statistical methods such as averages, means, and deviations. Statistical process control (SPC) charts were utilized to gain detailed information from the data.

3 SPARE PARTS BUSINESS IN THE CASE COMPANY

The case company of the study is the original designer of the equipment it sells. It owns the intellectual rights for the documents and drawings for the equipment and spare parts. The company works in a field, where the equipment life cycles can be up to 30 years. Thus, it can be said, that most of the parts in the equipment bill of material (BOM) can be considered a spare part at some point. According to Suomala (2001, p. 28) in the mechanical engineering and metal industry in general, spare part items are usually sold in small volumes per year and only a few items make the most of the sales. In addition to small volumes, high variability in the single items demand occurs over time. Due to these reasons, the case company has decided not to have a major inventory and it is providing spare parts for customers with make-to-order (MTO) principle. Meaning that only when order is received from the customer, the manufacturing of the product begins. Alternatively, if a product is subcontracted, a purchase order is placed for a supplier. This can cause long lead times depending on the item type and availability. Storages are kept on only a few strategical spare parts, which have high value for customers.

Equipment is constructed from parts, which can be divided into two categories. Commercial (standard) parts and parts that are manufactured based on the company’s own design. Standardized items have often multiple suppliers, which means that customers have more options for purchasing these. Parts, which are based on the company’s own drawings, cannot usually be purchased from elsewhere than the case company. Parts of the latter category can be priced with a premium. It is a common trait in the spare part business that nothing is being sold actively, but rather sales engineers are just reacting to customer needs. (Suomala 2001, p. 29-30.)

The customer needs can be divided into two classes, normal and urgent needs. Normal orders are planned beforehand by customer’s maintenance and parts are purchased in the storage, waiting to be installed. The urgent orders are occurring when customers face a sudden breakdown in their machinery and do not have a spare part in their own warehouse. These breakdowns can cause major downtimes and losses for the customer, so such orders need to be handled quickly. (Suomala 2001, p. 27.)

One key feature of the spare part business is product data management (PDM). When the customer is requesting a certain part belonging to its certain machine, the sales organization has to identify the part precisely. This is done based on material numbers, drawing numbers, machine serial numbers and part numbers obtained from the customer. For the case company, having up to 30-year-old machinery to be supported, the role of PDM cannot be underlined enough as a cornerstone of easy transactions. (Suomala 2001, p. 29.) In the case company, PDM is done mainly in SAP. In addition, drawings and documents held up to ten different places, such as hard-drives, designated software, paper folders, and microfilms.

In general, the inner quotation to order process in case the company consists of four different stakeholders in three different locations (A, B and C). These are divided based on operations (departments), where each has their own responsibilities. The operations in the case company are sales, purchasing, warehouse, and shipping. Their responsibilities are presented in figure 2 and discussed in more detail below. In addition to inner stakeholders, outer stakeholders of the process can be seen as the customers and manufacturing or subcontractors of manufactured parts.

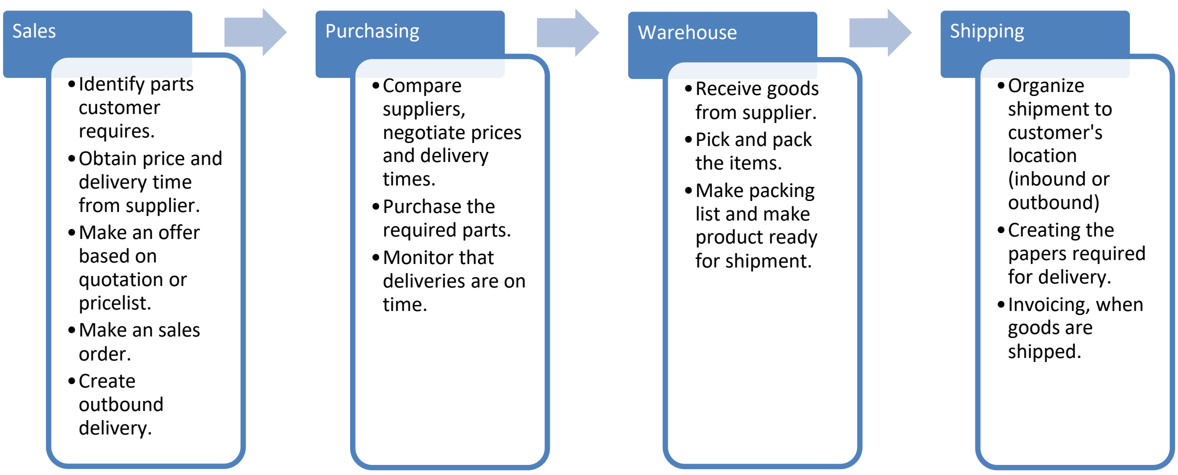

Figure 2. Quotation-to-delivery process in the case company.

The whole process starts with customers contacting sales engineer via email or phone and requesting a quotation for spare parts. Emails are sent directly to sales person familiar to the customer or into common email address used by various sales engineers. Phone calls are usually made when there is a rush with the spare part and the process needs to be handled urgently. A sales engineer identifies the product and seeks if it is a storage item. If not, possible price lists are checked from the key suppliers. If this is not available, historical data is examined and if sales are made lately (within months), price and estimated delivery time are obtained there. If not, a quotation is asked from a supplier, this being the case company's own manufacturing or vendor. The delivery date is promised for the product according to the offer or estimate, and by adding time for the rest of the value chain. The product is priced with a profit margin and the final quotation is sent to the customer. If the customer replies with a purchase order, a sales order is created and an order confirmation is sent for the customer with a promised delivery date. When the sales order is made, a purchase requisition is generated automatically by SAP against the parts that are required to fulfill the customer need.

According to Buzby et al. (2002, p. 513), the quotation and sales process are providing a tight link between the customer and the manufacturer. From the customer's point of view, this step has to be functioning seamlessly. The successful quotations process benefits the customer with accurate and quick responses. This can also provide an indicator of the company's customer service quality and efficiency.

The purchase requisition generated from sales order goes to the purchasing department's work queue in SAP. Purchaser looks, whether the sales department has a quotation asked for the product or not. In case a quotation has been requested, purchasing can look for alternative suppliers, negotiate on the price, delivery time and terms and make the purchase, based on the urgency of the case. If a quotation has not been requested by sales, purchasing has to ask for it separately.

Three different locations have divided responsibilities differently on who asks quotations, sales or purchasing department. In location A, the sales department mainly prepares quotation package with required drawings and forwards it to purchasing, which in turn asks for a quotation. In location B, the sales department asks for quotations directly from the suppliers without the help of purchasing. In complex cases, location B contacts purchasing. Location C is somewhere in between, where some sales personnel asks quotations themselves and some forward task to the purchasing department. When the quotation is received from the vendor, the best option is chosen and the purchase order is sent to the supplier. Purchaser is responsible to follow, that the promised delivery time by the vendor is kept and products arrive on time.

When the purchased product is delivered to the case company's warehouse, warehouse personnel does a goods receipt booking. This confirms that the ordered quantity is received to the warehouse. When all of the items in the customer's order have arrived, possibly from various sources, sales engineer does an outbound booking in which is stated that order is complete and can be sent to the customer. Outbound booking activates a picking request to the work queue of the warehouse organization in SAP. Warehouse personnel gathers or "picks" the items related to the sales order and transports these to the packing station. Goods are then packed accordingly to cover them from possible damage during the delivery process. The packaging list is created, which contains information about the insides of the package.

Warehouse personnel marks the packing completed and request for goods issue is generated to the SAP automatically. This indicates to the shipping department that goods can be delivered to the customer. Depending on the case, shipping organizes the carrier service to collect the goods from the warehouse and deliver these to the customer's location. Responsibilities on who organizes and pays for the delivery is based on what is agreed with the customer in the delivery terms. Carrier service is chosen based on what is agreed (sea, train, truck, plane) with the customer and what is the delivery time. Shipping documentation, such as waybill is created. Post goods issue is confirmed to the SAP when goods are moved to be the freight carrier's responsibility. After goods are shipped, an invoice is created corresponding the sales order items and possible shipping costs. Invoice is then sent to the customer via e-service, email or letter. In some cases, customer orders are sent directly from the supplier to the customer (inbound delivery). If done so, suppliers pack the products with the case company's packages and the case company's shipping department organizes the delivery to the customer.

Currently, the performance of the order-to-delivery chain is measured with two key performance indicators (KPI), the response time of the quotation process and on-time delivery of the products. Response time is measured with lead-time from the date customer is asking for quotation and the date when the quotation is complete and is sent back to the customer. On-time delivery of the product is measured from the promised delivery date and actual delivery date when goods are shipped to the customer.

4 LEAN IDEOLOGY

Lean ideology is essentially a strategy to achieve an objective, which focuses on creating efficient flow instead of efficient usage of resources (Modig & Åhlström 2016, p. 127). Resource efficiency is the traditional way of viewing efficiency, putting the perspective as one of the resource. It measures the extent, that certain resource is being utilized. This can be justified by the concept of alternative costs. For example, if a hospital decides to purchase new x-ray equipment, it has to be used as much as possible to make a profit. If the resource is being underutilized, you could have used your money elsewhere to gain better returns. In this case, the efficiency of the x-ray (resource) is being measured. To be able to get the best out of a resource, its usage needs to be organized in a certain way. There have to queue to the machine so, that it has always someone ready to be examined. This means that the customer suffers from the waiting period. (Modig & Åhlström 2016, p. 10-11.)

In flow efficiency, the viewpoint is set from the customer's perspective and it measures how much time is consumed from the beginning of a certain need to the point where that need is fulfilled. In the previous example of an x-ray machine, the hospital could make a strategic statement that it values the customer's time. Therefore, they shift the thinking; they measure the time between when customer need is first noticed and compare this to the point where x-ray images are taken. By doing this, the hospital can organize its processes in a way, which can minimize the customer's waiting period and offer better service. (Modig & Åhlström 2016, p. 13.) It can be said that value flows through the processes.

Flow efficiency can be defined to be the sum of value-creating activities divided with total time the task spent in the process (lead-time). The core idea is to maximize the value adding activities from the customer's perspective in a given time. Efficient flow is not about speeding up the value-creating processes but to eliminate unnecessary, non-value adding processes in order to improve the lead-time. This idea is presented in figure 3. If efforts are made to speed up the value creation process two times as fast as before, only a small effect is created to total lead-time. If the focus is moved to decreasing the non-value adding time of the process, great decreases in lead-time can be achieved. (Modig & Åhlström 2016, p. 28.)

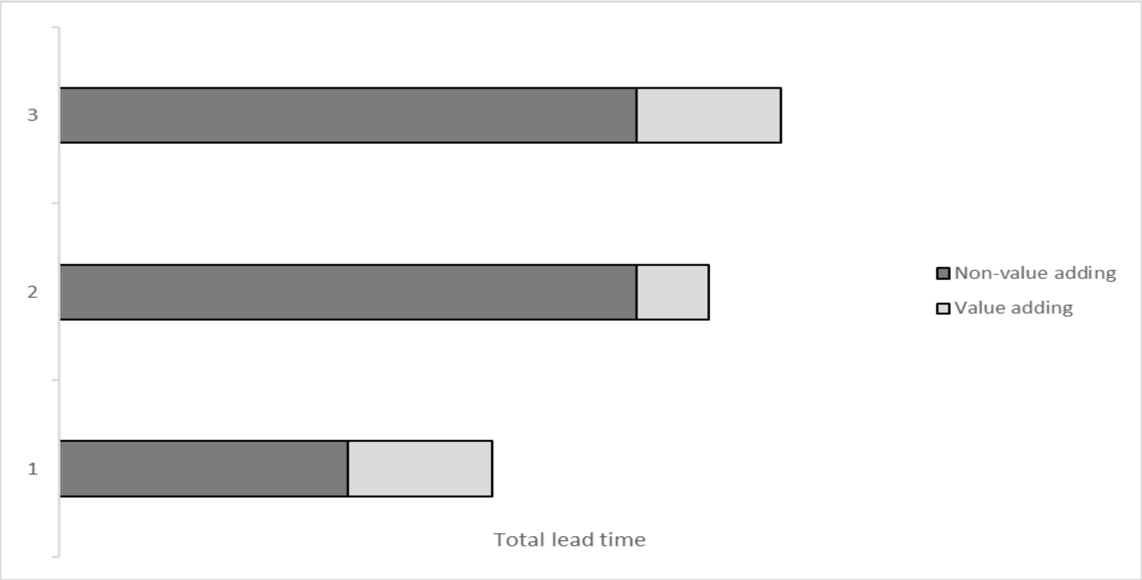

Figure 3. Value adding and non-value adding time, effect on total lead-time (Mod. Floor Tape Store).

Yet there is a conflict between flow efficiency and resource efficiency. According to Modig and Åhlström (2016, p. 15) utilizing the available resources as well as possible is a must in order to achieve economic success. As it is important to serve customers' needs with short response times. In lean thinking, these two aspects are to be balanced accordingly to the strategy of the company and correct lean methods are utilized to achieve these objectives.

4.1 Need, value and waste seen by the customer

One important idea of lean is to specify the value, which the system provides for the customer. According to Womack and Jones (1996, p. 16), lean thinking can help producers to specify that value. The value should be specified from the viewpoint of the customer as he/she sees it for a product, service or both combined. One should be put in the position of the customer, think what he/she requires from the service or product, and see how the information and material flow together through the system eventually fulfilling the customer need.

Customers, in general, have two kinds of needs, direct needs, and indirect needs. In the spare part business, direct need can be considered the requirement of certain spare parts and receiving those. This is a concrete need that customer wants to be fulfilled. The indirect need can be seen as softer values like, was the service done in a professional manner and handled quickly. (Modig & Åhlström 2016, p. 24-25.) The indirect needs (response and delivery time) have been highlighted in the case company's customer satisfaction survey.

To understand how the need of the customer is fulfilled, the process of value creation has to be determined. In the case company, the process can be set to begin when the customer first contacts the sales department and end when the quotation or eventually the product is received. (Modig & Åhlström 2016, p. 19.) This process consists of multiple stages, which according to Keyte and Locher (2016 p. 17 - 18) can be divided into three different categories. First, are the activities that produce value as seen by the customer. For example, when the sales engineer is processing the quotation or purchaser is buying the parts customer requires, value is added. The second group is the activities that do not create value for the customer but are necessary to support the need of the business. This could be for example updating material data to PDM-system to ensure smooth transactions in the coming years. The third form of the activities is those, which do not produce value seen by the customer. These activities can be for instance times when the customer's quotation is waiting to be processed in the email folder or ERP working queue. The process of the case company is divided into the categories more detail using value stream mapping (VSM) tool further in the coming chapter.

In lean, activities that do not provide value for the customer can be considered as waste. Different types of wastes in service organizations can be listed as follows:

1. Overproduction: too much is done too early or just in case. E.g. Unnecessary meetings with too many persons participating. Wrong priorities on what should be done next (something could be done later).
2. Inventory (WIP): all of the tasks that are started but not finished.
3. Waiting: the task is waiting to be processed. E.g., the task is waiting for more information from the customer, supplier or in the email box of an expert.
4. Re-doing: errors lead to failure demand, meaning that customer is not satisfied with the service and requests for re-processing. This uses capacity twice as it goes through. If incorrect data is forwarded into the next phase, it has to fix it or send it back to the beginning.

5. Motion: useless actions are done, e.g. data is entered manually, multiple systems are utilized, and data is entered to both by hand. Finding of needed knowledge (drawings).
6. Transportation: moving the task from one person to another or one department to another. Required persons per task or transportation between persons should be minimized.
7. Extra processing: doing work with too high quality, which the customer has not ordered. (Torkkola 2016, p. 27; Keyte & Locher 2016, p. 18.)

According to Sheddon and O'Donovan (2010, p. 15): "Waste cannot be removed without understanding its causes". These wastes and their elimination should not become the primary goal in lean process development. The waste originates from the variation, thus addressing the foundation of variation should be focused in more detail. If waste is however targeted, it should be eliminated from the bottleneck, where it matters the most. (Torkkola 2016, p. 27-28.)

4.2 Value flow and flow efficiency of the process

In lean, the flow of the value and its efficiency is in the center of focus. To gain a deeper knowledge of what causes the value stream to flow (or not to flow) three fundamental laws can be applied. Laws affecting lead-time and the performance of the value chain can be written mathematically. These are Little's law (queue theory), Theory of constraints and Kingman's formula on variation and utilization rate. These are presented in the following chapters. (Modig & Åhlström 2016, p. 31; Torkkola 2016 p. 186.)

4.2.1 Little's law

First is the Little's law on queues in a system, created originally by John Little in 1961. It states that the time required to finish the task from the customer's point of view (lead-time, CT) is affected by the amount of work-in-progress in the system and the speed task is finished. This can be written as follows:

$$CT = \frac{WIP}{TH} \tag{1}$$

In equation 1, *WIP* is work-in-progress (task entered the value stream but not completed) and *TH* is throughput (average output of a production process in a time unit). (Little & Graves 2008, p. 93.)

According to the law, lead-time can be affected by either decreasing the systems work-in-progress or increasing the speed of which tasks are completed. In real life, increasing the speed of the workers doing their tasks might be complicated but decreasing or limiting the amount of WIP is easier to accomplish. Yet it is not optimal to decrease the WIP to zero. If done so, the throughput or the performance of the systems is halted. (Torkkola 2016, p. 189-190.)

4.2.2 Kingman's formula

In addition to work-in-progress, lead-time is affected by variation and utilization rate of the resources. John Kingman generated a formula in 1960 connecting these elements. It states that lead-time (CT) increases if average processing time increases, variation increases or utilization rate of the system increases. Kingman's formula presented below:

$$CT = V * U * t_e \tag{2}$$

In equation 2, V is variation, U is utilization rate coefficient and t_e is effective processing time. (Torkkola 2016, p.192.) Variation in Kingman's formula is determined as follows:

$$V = \frac{c_a^2 + c_e^2}{2} \tag{3}$$

In equation 3, c_a is coefficient of variation, arrival (demand from the customer) and c_e is coefficient of variation, effective (variation within system/request) (Torkkola 2016, p. 193).

The effect of variation to lead-time is significant, as coefficients are squared. The variation can be divided into three different categories; variation due to resources (e.g. different skill levels between workers), variation due to the task at hand (e.g. one item per order versus 10 items per order), variation in daily demand (each customer have needs regardless of others). (Torkkola 2016, p. 192-193.) In the case company's business, demand from customers varies on a daily basis and almost every request is concerning different spare part. In addition to variation, Kingman's formula consists utilization rate coefficient U which can be calculated:

$$U = \frac{u}{1-u} \tag{4}$$

In equation 4, *u* is utilization rate of the system (Torkkola 2016, p.159).

This formula is underlining, why lean ideology does not optimize resource efficiency or maximum utilization rate of the resources (efficiency paradox). The utilization rate of the resource increases the coefficient U exponentially, which can be seen in figure 4. If the utilization rate u is 80%, coefficient U increases the lead-time fourfold. Therefore, if the utilization rate of a resource is optimized towards 100%, lead-time approaches infinity. In lean methodology, utilization rate should be kept below 80%, to be able to answer customer needs in short notice. (Torkkola 2016, p.25 & 196.) If high variation and high utilization rates are combined in a system, long lead-times for customers are sure to follow.

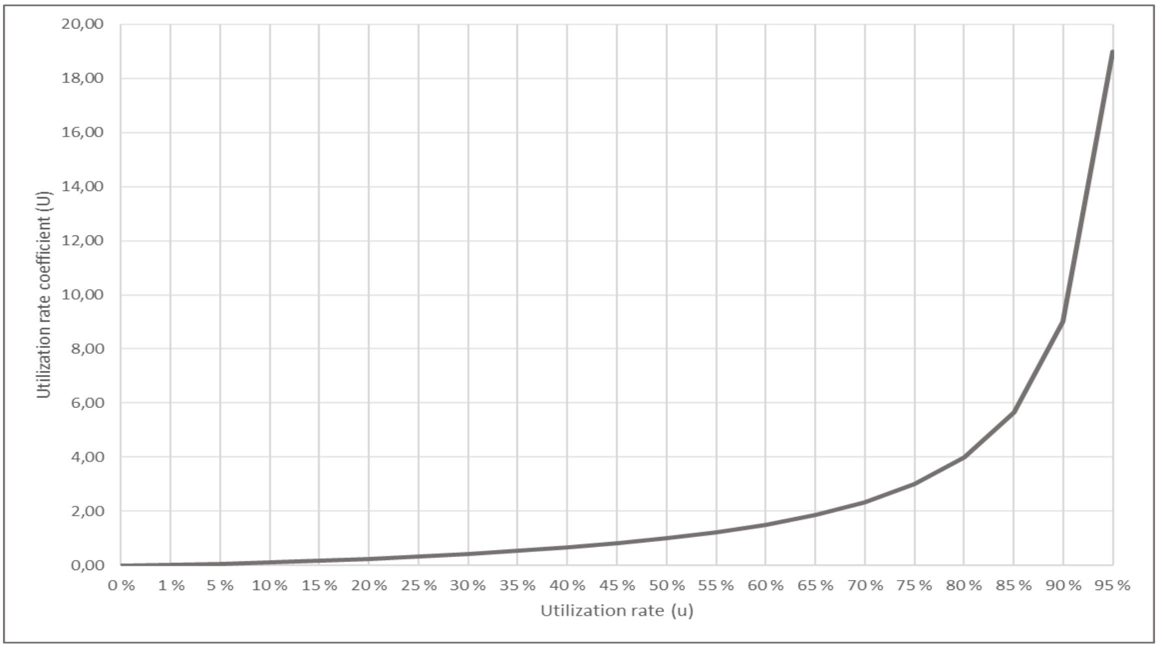

Figure 4. Utilization rate coefficient as a function of utilization rate of a system.

When transaction processes (sales, purchasing) or manufacturing are made, some errors occur eventually. These errors in quality are one cause behind work-in-progress and thus lead-times. Quality errors are the worst type of lean wastes and the most expensive one. It is directly related to the customer dissatisfaction, it causes queues and requires re-working efforts, which consumes capacity. This is why one of the main lean targets is to achieve perfect quality and zero defects. (Karjalainen 2014.)

In transactional work, errors can be identified for example as follows; data is missing and operation cannot be done or data is unclear and additional data has to be asked. In addition, if data contains mistakes and it cannot be processed or the mistake will forward to the next phases, prioritizing rules are not obeyed or the customer is not satisfied with the service and returns task for re-working. These errors are affecting the possibility to do the work correctly on the first time. The probability of doing things right in the first try for a system is called rolled-throughput-yield (RTY). It can be calculated by multiplying the probability of success of every individual process step's success with each other. (Torkkola 2016 p. 200 & 204.)

This is presented as an example in figure 5, for a four-step process. Each of the steps or departments have a 90% chance of succeeding at the first try. This means, that they face an error on 10 % of the occasions. RTY for the process could be then calculated as 0.9^4 = 65.61%.

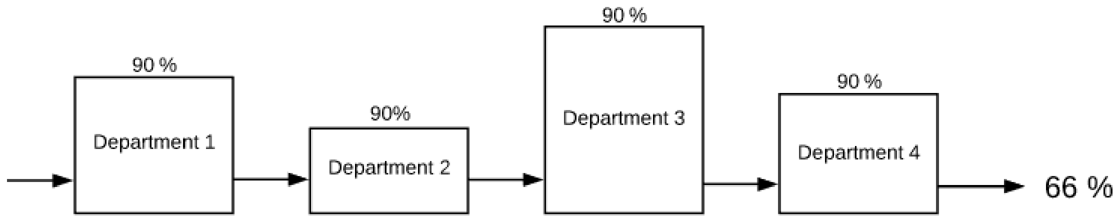

Figure 5. Four step process, rolled-throughput-yield (Mod. Torkkola 2016, p.204).

As stated earlier, utilization rate of a process is one of the contributors to lead-time. Errors in turn have an effect on the utilization rate. Each error made usually means that something has to be re-worked. This correcting of errors and re-working consumes the capacity. (Karjalainen 2014.) According to Torkkola (2016, p. 201), utilization rate increases while probability of success decreases (need of re-work appears). The coefficient of errors on utilization rate can be written as follows:

$$\frac{1}{1-p} \tag{5}$$

In equation 5, p is the probability of errors (Torkkola 2016, p.201).

If there were a system with RTY of 90 %, it would mean, that the coefficient of errors on utilization rate would be 1/ 0.9 = 1.11. For the 80% utilization rate, the effect of errors would increase the utilization rate of the system from 80% to 89% (0.8*1.11 = 0.89). Meaning, that errors create a need for an additional 9 % of capacity (re-working and corrections). This increase in utilization rate again increases the lead-times radically, as presented earlier in figure 4 (effect of utilization rate on lead-time). By eliminating errors occurring in the process, additional capacity can be freed without the need of investments on new personnel or machinery (Karjalainen 2014). Torkkola (2016, p. 203) claims, that if no data is available from errors, a rough estimate can be made, where each working stage has an error probability of 5%. This is being optimistic estimation, and the situation is likely even worse.

Besides eliminating the errors, capacity can be added by simplifying the system. This decreases the possibility of errors happening in the first place. If we would eliminate one process step from figure 5's example, the RTY would increase to 0.9^3 = 73 % instead of 66 %. (Torkkola 2016, p. 204-205.)

4.2.3 Theory of constraints

The third theory is the theory of constraints (TOC). Process or system, which consists multiple work stages usually contains unbalanced workloads and capabilities between different steps. This leads to the difference in average lead times among the process stages. The operation, which is lacking the speed, can be identified as the bottleneck of the system. The theory of constraints explains, that the throughput of the whole system is eventually determined by this one bottleneck. If this constraint can be improved, the efficiency of the system increases. On the other hand, if improvements are done to non-constraints, no improvement is done in the system, as the bottleneck is determining the throughput. A visualization of constraint in a system is presented in figure 6. In it, processing rate of each department is represented by its size and value above. Demand of ten tasks enter the systems daily. It can be seen, that department 2 can only produce six tasks per day, and it sets limit for the whole system's output, which is six tasks per day. (Groop 2012, p. 27-28.)

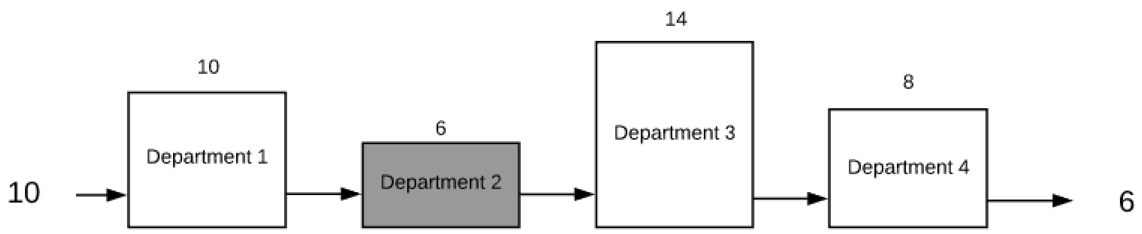

Figure 6. Input, output and constraint in a system of four departments (Mod. Groop 2012, p. 28).

Eliyahu Goldratt, who originally introduced TOC, presented also a tool for utilizing it in practice. This is called the five focusing steps (5FS). The process focuses improvement efforts of five steps where they matter the most – on the constraints. (Groop 2012, p. 38-42.) The five focusing steps are presented following:

1. Identify the system's constraints; determine the system's step, which capacity is less than the demand placed on it. Usually WIP is stacking ahead of the constraint (Torkkola 2016, p.98).
2. Exploit the system's constraints; maximize the efficiency of the recognized constraint. All of the work that is not necessary to be made in the constraining phase should be shifted elsewhere or eliminated. Idea is to get the best performance out of the current system without major investments.
3. Subordinate everything else to the constraint; organize and synchronize all the non-constraint operations to support the constraint. Meaning that constraint should never be waiting for a task and the quality of the input should be inspected before it moves to constraint. Work releasing sequence could be set at the rate of constraint's capacity.
4. Elevate the capacity of the constraint; this step includes the possibility of additional workers or equipment for the constraint thus increasing its capacity. This option should be in careful consideration as the constraint might re-surface at other production phase where it is more difficult to manage.

5. Feedback loop to step one; If the original constraint has been broken, it has reappeared to somewhere else in the system. Process of the 5FS has to be repeated. (Groop 2012, p. 38-42.)

Before moving into the five focusing steps and determining what is limiting the performance, one has to set the goal and meters. Goal should be in line with the purpose of the process and spread system-wide, to prevent sub-optimization. (Groop 2012, p. 36-37.) For example, goal for the spare part process should be operational excellence, meaning that value is eventually gained on the bottom line and more profit made. This again requires sales personnel having more time to sell more products and services, going on “offence” or providing better service, which in turn could attract customers. (Duggan 2012, p. 61.) Efficiently flowing value stream could provide the needed time, as not all of the time is consumed on surviving. Then, system-wide measure should be implemented to know, whether individual actions are improvements. Suitable measurements are for example throughput, inventory and operating expense. (Groop 2012, p. 38.) In this thesis, theory of constraints is utilized in order to find the bottleneck in the current order-to-delivery process. It offers a way to focus the utilization of other lean tools to the point where they have the greatest impact.

Based on these three laws, four things can be done to improve flow efficiency or decrease the lead-time as experienced by the customer. The system’s work-in-progress can be decreased, by eliminating the reasons behind bottlenecks (WIP stacks in front of a bottleneck) and setting limitations and rules on how many works can be open at a given time. Workers can work faster on their tasks, which decreases the throughput-time. Similarly, decreasing causes of variation in throughput-times will assist. Resources can be added to a work phase, which increases the capacity, leading to lower utilization rate, which results in shorter lead-time. More capacity is available also via decreasing the number of errors made or via simplifying the system. Alternatively, different sources of variation can be eliminated or alleviated and the variation term of Kingman’s formula decreases. (Modig & Åhlström 2016, p. 45.)

4.3 Side effects of focusing on resource effectiveness

Focusing mainly on the effective usage of resources results in different additional, unwanted side effects. These again are creating additional work that has to be answered. According to Sheddon and O'Donovan (2010, p. 15), demand entering the system can be divided as value demand and failure demand. Value demand is the reason why an organization exists (e.g. quotations and sales orders) and failure demand is caused by errors of not being able to do something right in the first time. The failure demand can be causing the largest part of waste in transactional service processes. The primary cause for failure demand is the system's failure to answer the varying customer demand in the first place.

These failure demands are caused by additional needs from three different factors. Long lead-times, many flow units in the system (WIP) and need for re-starting the task. Long lead-times can cause secondary needs that were not apparent in the first place. It causes waiting, which causes loss of inspiration, forgetting and possibly losing the interest towards the whole case. The customer might end up calling and asking the status of his case, this being a call that was not needed in the first place. (Modig & Åhlström 2016, p. 48 -50.)

The second factor is the multiple tasks to be handled at the same time. The longer it takes to complete the task, the more tasks are stacking up. The amount of, for example, emails can be causing stress. At the same time, the additional need for sorting and prioritizing the emails is present (primary task being on answering, not sorting). As the emails are stacking up, resource efficient organizations start to multitask. Finally, when the limits of the human mind's memory are reached, tasks are forgotten and errors start to occur. (Modig & Åhlström 2016, p. 52 -54.) Multitasking and shifting between tasks should be avoided, as this consumes the capacity (Torkkola 2016, p. 52).

The third cause for additional work is the re-starting of the tasks. When for example, email is read and task started, somehow new and more important tasks appear. The original task is left and picked up when the more urgent is handled, causing additional re-starting time. The original task might be so difficult, that it takes many reads to remember the case again. It can also turn into a "hard" case in the human's mind and mental set-up time to take the task is increasing. (Modig & Åhlström 2016, p. 55 -56.) In the case company, this happens a lot, as the focus is often moved between tasks more urgent than the first ("firefighting mode").

Together these three causes are leading to many forms of failure demands and additional needs, which were not present in the first place and are consuming the capacity of the system.

4.4 Lean tools and methods

Lean is originally from the manufacturing industry, but it has shown promising signs of success in the service industry as well. Many lean concepts found in manufacturing can be adapted to the service industry with no or only little variation. (Keyte & Locher 2016, p. 1; Chiarini 2013, p. 17.) The lean office can be defined by decreasing waste and increasing value adding time in transactional processes. One of the best lean tools for this purpose is value stream mapping. (Chiarini 2013, p. 142-143.) In addition to VSM, other possible lean tools for transactional processes are presented in the coming sub-chapters.

4.4.1 Value stream mapping

Managing previously defined value streams requires understanding and improving the flow, managing its different interactions between various tasks and measuring it. This is done in order to keep the costs at minimum and service and products competitive. Value stream mapping can be considered as a tool to manage the value stream. Its purpose is to document and measure the relations between work phases and eventually organizations. The tool is designed so, that it captures the ways of working and visualizes those. When the value stream is visualized system-wide, problems occurring in the system can be pointed out and focus on the spot that will cause the greatest change. Example of value stream map is presented in figure 7. (Keyte & Locher p.1 & 5.)

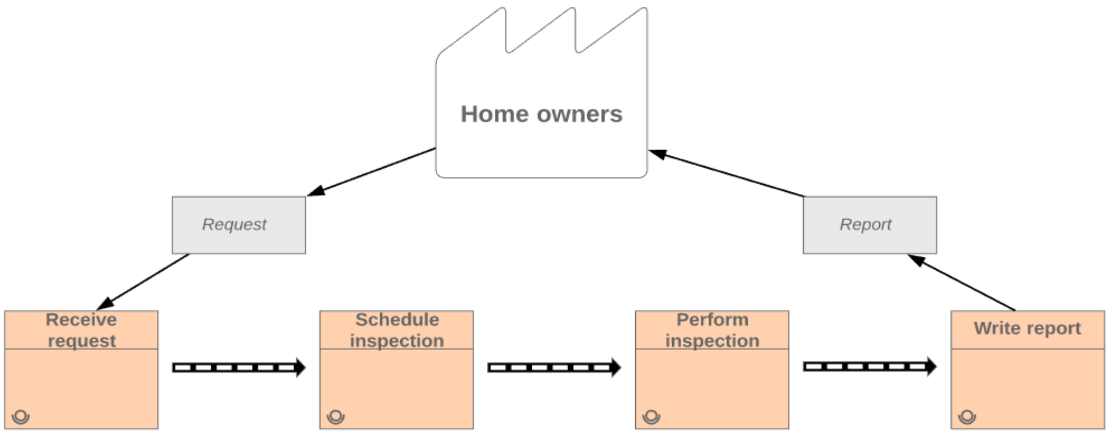

Figure 7. Example of value stream map (Mod. Keyte & Locher 2016, p. 3).

To deliver a service and eventually a product, plenty of different activities are made. Lots of information is handled and it is transported in electrical formation, making it less visible compared to typical material flow. Prioritization and the way of doing knowledge work are usually up to each expert, meaning that there are no standards of work. In addition to this, usually, experts are driven into multitasking, which causes even more difficulties to keep track of what is going on. Typically the company is divided into departments, in the case company these being sales, purchasing, warehouse, quality, and shipping. These departments are forming silos, which each are optimizing their own performance. Interactions between departments are not known properly, especially in the areas of information handoffs, work handoffs, roles and responsibilities, which causes problems. (Keyte & Locher p.5-6.)

As Womack and Jones (1996, p. 37) states in their book: “Just as activities that can’t be measured can’t be properly managed, the activities necessary to create, order, and produce a specific product which can’t be precisely identified, analyzed, and linked together cannot be challenged, improved (or eliminated altogether), and, eventually, perfected.” A value stream map is a tool for this.

4.4.2 Root cause analysis

Business processes like spare part sales contain multiple different work stages, which each effect on the result seen by the customer. This means that there are multiple cause-and-effect relations on why the transaction was successful or not. Ishikawa’s cause-and-effect diagram or fishbone diagram is a commonly utilized lean tool to visualize these causalities. It is drawn in the form of a fishbone, to illustrate possible causes for the known problem by classifying and sorting. An example of an Ishikawa diagram is presented in figure 8. (Aartsengel & Kurtoglu 2013, p. 455.)

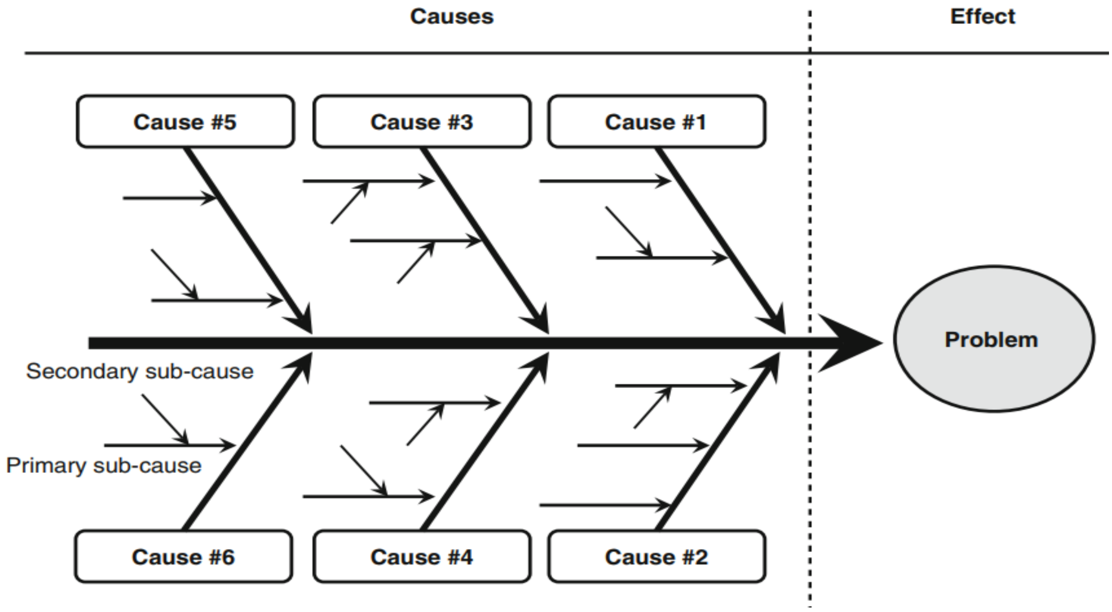

Figure 8. Ishikawa diagram (Aartsengel & Kurtoglu 2013, p. 456).

According to Torkkola (2016 p. 98), major causes for the defined problem can be classified in the service industry as follows: personnel, methods, required information, information systems, environment, and metrics. For the Ishikawa diagram, it is important to focus only on one problem at a time, as the narrower, the definition, more detailed analysis follows. Idea is to obtain the knowledge on the root-cause for the problem. When one cause is identified, one should ask what is the cause behind it. Eventually, the root-causes are found for the defined problem. (Aartsengel & Kurtoglu 2013, p. 457.)

Another useful lean technique to determine root causes for occurred problems is the 5-why questioning. Its idea is to ask the question “why” for five times to reach for the root cause. On each question, the reason gets more accurate and detailed. When the root cause is figured out, actions to fix things should take place if possible.

4.4.3 Gemba walks and interviews

In addition to numerical data, interviews should be conducted to gain knowledge of the current state of the work. Gemba walk is a lean tool for this purpose. Gemba is a Japanese word, which refers to the “real place” where the work is actually done. Its idea is that the person who is in charge (manager, developer) goes to meet the people doing the tasks and understands how things work in reality and why something is done as it is. Gemba walk is conducted from the customer's point of view, via the value stream from the start to the beginning. This way, the whole chain is analyzed and the critical points of where information is transferred. At the "real place", questions are asked from the persons responsible for the tasks, while doing the work. (Torkkola 2016, p. 125.) Questions that could be asked during the Gemba walk can be seen in Appendix I.

4.4.4 First-in-first-out as a prioritizing rule

According to Torkkola (2015, p.136), First-in-first-out (FIFO) is a prerequisite for an efficient process. If the processing sequence of tasks is changing, this variation is directly transmitted to variation in the lead-time of the process. Decreasing variation can be considered as one of the main goals on the road to process efficiency. By using FIFO, there is no need to prioritize tasks when they move between organizations and no more working time is required in thinking of what to do next. (Torkkola 2015, p. 136.)

If FIFO is utilized as the standard prioritization method, experts no longer need to go through their list of tasks in email or ERP-system. This releases them of reading cases repeatedly wondering which to choose next. Usually, when FIFO is not utilized, lead-time is unpredictable. As the lead-times are unpredictable, the need for rushing is generated from the customer viewpoint. Considering that customer has been served with varying response time in the past, bad experience suggests that rushing is needed to get an order through quickly. However, if response times can be stabilized to a predictable and fast level, no rushing is needed in the first place. For FIFO to succeed, experts need to receive the task from only one route. (Torkkola 2015, p. 136-138.)

In addition, FIFO integrates different organizations to work more in sync with each other. In case tasks are not prioritized with FIFO, one team might be focusing to work with high efficiency but not on the same tasks as the previous link in the chain. This causes variation in the total lead-time. FIFO work queues can also be set to some maximum limits, which helps to control WIP. (Torkkola 2015, p. 139.)

4.4.5 Statistical process control and problem-solving

Performance meters or KPIs on response time and on-time delivery are telling how we did (good/bad), but these do not indicate why. In addition, these do not give information regarding on what to change or do differently. They do indicate that there is a need for improvement. If one wants to improve performance, process meters should be utilized. (Torkkola 2016, p. 163; Wheeler 2000, p. 21.)

To properly understand a system or a process, averages are not sufficient metrics. This requires a basic understanding of variation. For this purpose, statistical process control (SPC) or other measures should be utilized. With the SPC chart, a time series of events is drawn, which points out the variation of certain activity and visualizes its performance. (Torkkola 2016, p. 158.) In SPC, variation can be divided into two categories; routine variation, which is due to common causes and exceptional variation, which is due to assignable causes. The process can be said to be predictable or stable when it does not show exceptional variation. (Wheeler 2000, p. 142.)

According to the theory created by Walter Shewhart, the limit that determines exceptional and routine variation statistically is set to be a 3-sigma limit. This is three standard deviations away from the average, covering up to 99.7% of the cases. Idea behind this is that when limits are set far enough from the average, majority of the cases fall inside the borders. This way, it is probable that the few cases crossing the limit have some special reason and these are economical to look trough. When a certain value or event is above this 3-sigma limit, it is considered an exceptional variation of the process and there is some assignable cause for it. This should be understood as a signal from the process. Each of these cases should be examined thoroughly for its root cause and the cause canceled out. (Wheeler & Poling 1998, p. 133.)

Dividing variation into categories offers a beneficial way to filter out the noise, and focus efforts on the real issues. Example of the SPC chart of location C’s response time for each individual quotation of the period (each dot is lead-time of one quotation) is presented in figure 9. It can be seen, that there are two cases above the upper control limit. This means that the system is not predictable and assignable causes behind the cases should be examined.

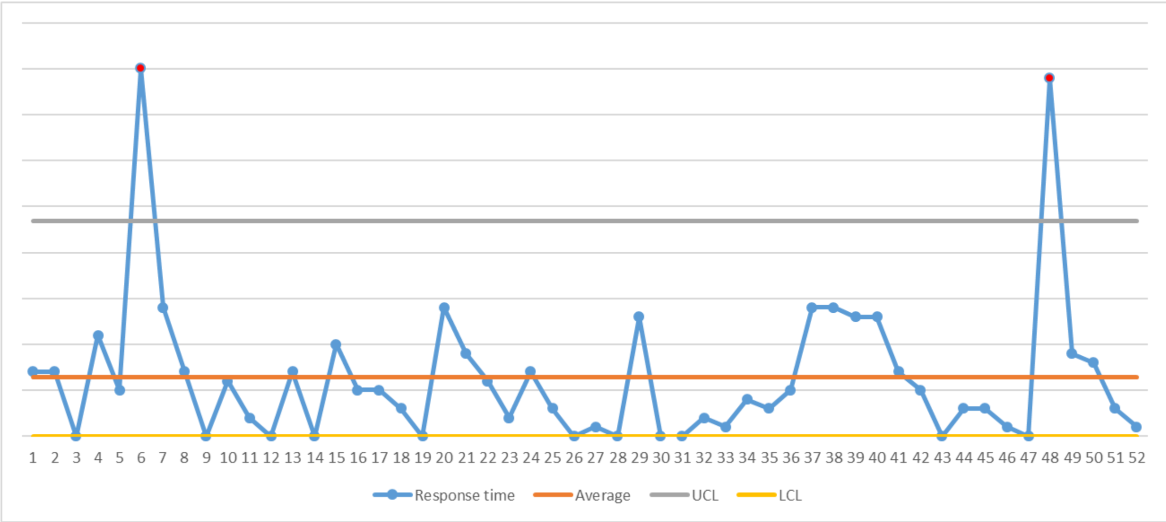

Figure 9. SPC chart of location C's response times to quotations in September 2018.

To calculate the 3-sigma limits, average of range (X) and moving average of the range (mR) need to be calculated beforehand. Formula for upper control limit (UCL) is as follows (Wheeler 2000, p. 41):

$$UCL = X + 2.66mR \tag{6}$$

In equation 6, 2.66 is a scaling factor (Wheeler & Poling 1998, p. 137). The lower control limit (LCL), can be calculated as follows (Wheeler 2000, p. 41):

$$LCL = X - 2.66mR \tag{7}$$

According to Little's law, what should be measured with SPC-chart is work-in-progress, amount of completed tasks per time unit and lead-time of each individual task. If the first two can be stabilized, lead-times are to be stabilized. Kingman's formula states that one should measure the utilization rate (incoming tasks in relation to completed tasks) and variation, which is seen from the chart. (Torkkola 2016, p.164.)

For the examining of reasons behind assignable causes, the A3 report could be utilized. This is a lean tool using the plan-do-check-act (PDCA) cycle, which Deming originally presented. It gained its name from A3 sized paper, where the PDCA cycle is implemented as a logical flow, from left to right and from problem to solution. (Ayulo 2016, p. 37.) A3 is conducted as a team, and it forces the people into learning problem-solving skills and turning it into a routine (Torkkola 2016, p. 33).

An example layout for A3-paper was constructed for the case company and this can be found in Appendix II. It consists eight different blocks where steps 1-5 are being the “plan” phase, step 6 is “do” phase, step 7 is “check” phase and step 8 is “act” of the PDCA-cycle. In the planning phase, the problem is recognized and the point of focus narrowed. A target for the improvements is determined and the root cause behind the problem figured out. Then countermeasures against the found root cause are developed. For the “do” phase, an implementation plan for the countermeasures is conducted, including timetables and hypotheses on what should happen. For the “check” phase, results of countermeasures are evaluated, whether improvement occurred or not. Then in the “act” phase, successful countermeasures and ideas are standardized along with the organization. If the idea was not successful, it is abandoned immediately and the cycle returns to the beginning. (Ayulo 2016, p. 37; Torkkola 2016, p. 36.)

5 CURRENT STATE ANALYSIS OF THE VALUE STREAM

To evaluate the current state of the organization objectively, numerical data is gathered from the SAP ERP of the case company. SAP has been in use from 2006 and it is used to manage all daily business operations handled in the case company ever since. Each operation made, each individual purchase or sales order leaves a time stamp when it is made. This way data is widely available from all of the steps in the order-to-delivery chain. Data can be acquired using various built-in transactions in SAP. For example, one transaction in SAP provides the date when the sales order is created and it contains the number of the sales order. Another transaction provides the date when the purchase order is made and the sales order number. Raw data is then exported into Microsoft Excel and combined using common factors, in this case, sales order number. This way data for the whole value chain was gathered, which enabled the lead-time calculations.

For example, the response time for the customer's request for a quotation could be calculated by comparing the date when the request has arrived and the date when the completed quotation is sent from the system. Work-in-progress calculations are done in a way, that each task entered the limited part of the value stream (quotation, sales, purchases, and shipping), but is not completed is counted as WIP. When the task is completed, it exits the pool of WIP. For example, the WIP in the quotation process can be counted as follows: if the request is received in 3.1.2018 and it is completed in 5.1.2018, it stays within the process for two days as work-in-progress. The same logic is utilized in lead-time and WIP calculations throughout the value-stream. Calculations made in the following chapter are collected to the value stream map seen in Appendix III.

To stay within the scope of the study amongst the vast amount of data, the gathering is done for the year 2018 alone. In addition, operations are filtered so, that only transactions made within Finnish spare part operations; sales, purchasing, and shipping are taken into account.

Gemba walks were done with sales engineer and sales manager, purchasing managers and shipping manager. These were in the form of "basic training", which each department would give to a new employee. During the training, questions from Appendix I were asked. In addition, meetings with open discussions were made with sales teams and purchasers in all of the three locations, regarding the current state and the issues faced by each individual. Based on this knowledge, the current state of how work is done was obtained. Notes from the meetings are in the possession of the author.

5.1 Sales organization

The sales organization is responsible for the quotation process, order process, and outbound process. Each of these processes was considered as a limited part of the system. For the quotation process, dates, when each individual request for quotation (RFQ) arrived from the customer, was collected. These dates were then compared to the date when the quotation was ready and sent back to the customer. This way, lead-times and WIP's were calculated for each of the three location's quotation process. From the lead-times for each case, averages, medians, and standard deviations could be calculated. Large variation was noticed in the lead-times between different cases. This is presented in figure 10 in the form of SPC-chart. Each individual order is one beam (case number on the x-axis) and lead-time is in the y-axis.

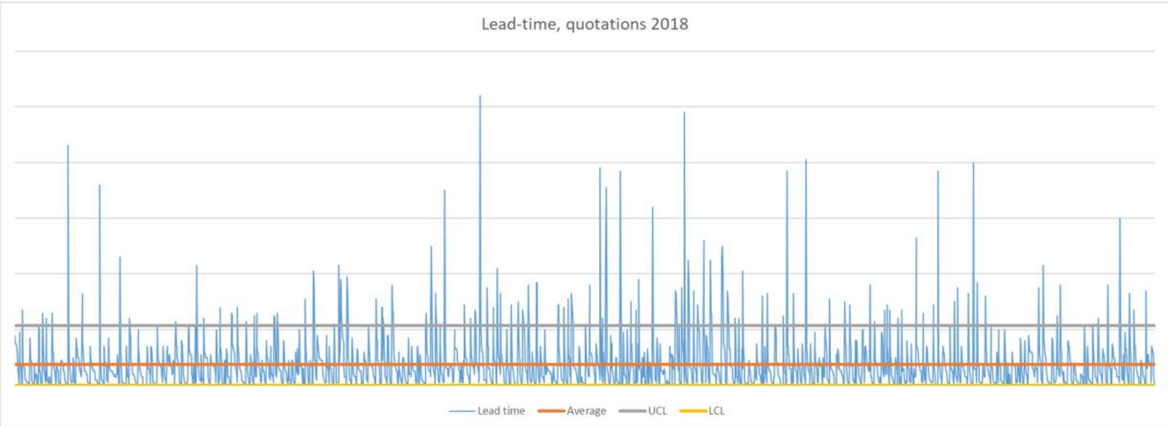

Figure 10. SPC-chart of quotation lead-times.

Then, the ordering process was evaluated. Dates from each individual purchase order sent to the team were collected. This was compared again to the date when the customer received the order confirmation. Lead-time and its average, median and standard deviation values of the sales process from each location was calculated together with WIP.

One part of the sales organization's responsibility is to do the outbound booking. This can be done, when all of the items have arrived for certain sales orders, meaning that the order is ready to be delivered. Dates were collected on each item's arrival to the case company's warehouse. Then, the arrival date of the latest item in sales order was compared to the date, when sales personnel did the outbound booking. Lead-times of the process and work-in-progresses were calculated.

5.2 Purchasing and warehouse

When sales create the order acknowledgment to the customer, simultaneously purchase requisition is made against the parts required to fulfill the order. This means, that the order confirmation date is the date when the task has moved into the purchasing department's queue. This date is then compared on the date when the purchase order has been sent from the system to the supplier of the goods. Each individual case's lead-times, averages, and WIPs were calculated to measure the purchasing department's performance.

When the supplier finishes the items, it has two opportunities, either in doing outbound delivery, which goes via the case company's warehouse or inbound delivery where items are shipped directly from supplier to customer. Items that are shipped with an outbound option, the warehouse does goods receipt booking when receiving products. This receiving date is used in the outbound booking- calculations presented previously. When sales have done the outbound, the warehouse can pick and pack the items ready for shipment. The date when products are packed is compared to the outbound date of the sales department. This way lead-time of how long the warehouse in each location handles individual cases could be calculated.

5.3 Shipping and invoicing

When the packaging of the products is done, the task moves to the queue of the shipping organization. Lead-times and WIP's could be calculated for the shipping process by comparing packing date and date when shipping the organization has done post goods issue booking. This is the confirmation, that items are shipped from the warehouse towards the customer. After this is done, the shipping department does invoice related to the items that were shipped. Lead-times for this could be calculated based on when the post goods issue had been created and when the invoice was created.

Items that were shipped through inbound option could not be measured, as of date from when items left from the supplier were not easily available for the cases. Yet all of the workload going through sales and more than 66% of the events going through shipping is covered in the study. This way, the intervals of each step of the process could be evaluated numerically.

5.4 Current state VSM for the process

Value stream maps were drawn for each individual location to find unique features based on the data acquired and information gained from the Gemba walks. Appendix III presents the value stream map of location A. In the VSM, average lead-times and work-in-progress for a process are shown based on the calculations presented earlier. Cycle times had to be estimated, as each individual case varies greatly in length and no reliable data can be gathered from this. The best estimate from the sales experts was, that each case takes somewhere between fifteen minutes and three hours of active work if all the required data was at hand or somewhat easily obtainable. Based on these assumptions, it takes several days from the customer requesting a quotation to actually receive the product. This considers only the inner process of the case company, meaning that supplier delivery time and customer delay to make the purchase decision are not counted in. An estimate of the value-adding work could be calculated from the customer's point of view. This makes the total value added time of the value stream to be x %. The value cannot be calculated accurately due to the approximation of cycle times. Yet it can be considered directional regarding the value creation ability of the spare part process.

It can be seen from the VSM that the bottleneck of the whole value stream is in the quotation process, as its lead-time is the longest and the average amount of work-in-progress is the highest. This is partly due to the prioritizing rule of the sales organization in location A, which focuses on order processing over responding to new quotes. Based on the theory of constraints, the focus of the developments should be aimed in the quotation process. In addition to quotation, order and outbound processes have to be considered, as these share the same sales resources and are thus tightly linked. From here on, the rest of this thesis is mainly considering the area of sales department. Yet as the long delivery times were at the top of customer dissatisfaction and up to 50 % of the inner process' lead-time is caused elsewhere than the sales department, some effort is given to consider reasons behind this.

5.5 Types of wastes in the current value stream

As the value adding time of the process can be considered low, many different types of wastes can be identified. These were noticed during the Gemba walks and open interviews with the teams. The most significant one is the waste of waiting and this is occurring through the value stream in each step. In quotation and order processing, the task is waiting to be processed, waiting for missing information from the customer, waiting for price and delivery information from the supplier. In outbound process, tasks are waiting for sales personnel to check whether items are ready to be delivered. The waste of waiting is strongly connected to the waste of inventory (WIP). As tasks are started but cannot be finished due to previously stated reasons, the WIP level rises. A high level of WIP increases the lead-time of each individual task entering the system. In addition, a large number of work-in-progress causes additional sorting and filtering of the tasks from the work queue for the sales personnel.

Waste of motion can be identified, as the personnel in the quoting process are looking for the needed knowledge (drawings) from multiple locations such as drives, software, and physical archives. This causes high variation in the system and long lead-times in some cases. Under the waste of motion goes manual data entries to multiple systems, in SAP and data management system (DMS) for example.

Waste of overproduction can be noticed, as some of the tasks are gaining too high priority and are finished too early. This originates from the prioritization rule of the tasks based on “who shouts the loudest”- method and the best determination by sales engineers. No accurate knowledge on the true urgency level of the case is usually available and urgencies are quite subjective. For one it is within the same day and for one it is in a few weeks. Because of this, relatively “easy” cases are eventually buried under urgent cases. This causes variation to lead-times in all of the stages in the value stream.

Waste of re-doing is caused by the errors made in the process. For example, the sales department is requesting for purchase without sufficient information (quality, painting, etc.). Purchasing has to obtain the needed data by asking from sales or figure it out themselves. Similarly, errors or long lead times cause additional failure demand, where customers are requesting status updates. These questionnaires are not needed in the first place if the system works fast and reliably.

5.6 Demand, completed tasks, lead-time, and WIP of the sales process

A more detailed study of the sales process is done in order to find causes for long lead-times. Gathered data is combined with SPC-charts to analyze it properly. SPC-charts are constructed for demand arriving at the sales team, tasks that sales team completes, lead-time of each case and work-in-progress for a given time. Charts presented in this work is combining all of the locations, but similar charts were done from the data for each individual location. This way analysis could be made into a level that is more accurate and noise from different locations could be canceled out. First, the demand faced by the sales organization is evaluated. This is done by comparing how many requests for quotations and purchase orders arrived at the spare part team on each day over the year (figure 11). To make the chart more readable, data were combined based on weeks. On the x-axis is the arrival week of a task and the y-axis contains data on how many individual tasks arrived. It can be seen that daily demand is varying, but it stays within control limits. Demand arriving from customers can be said to be predictable. In addition, the highest peaks of tasks seem to arrive during spring and fall. Periods during summer and New Year are the quietest.

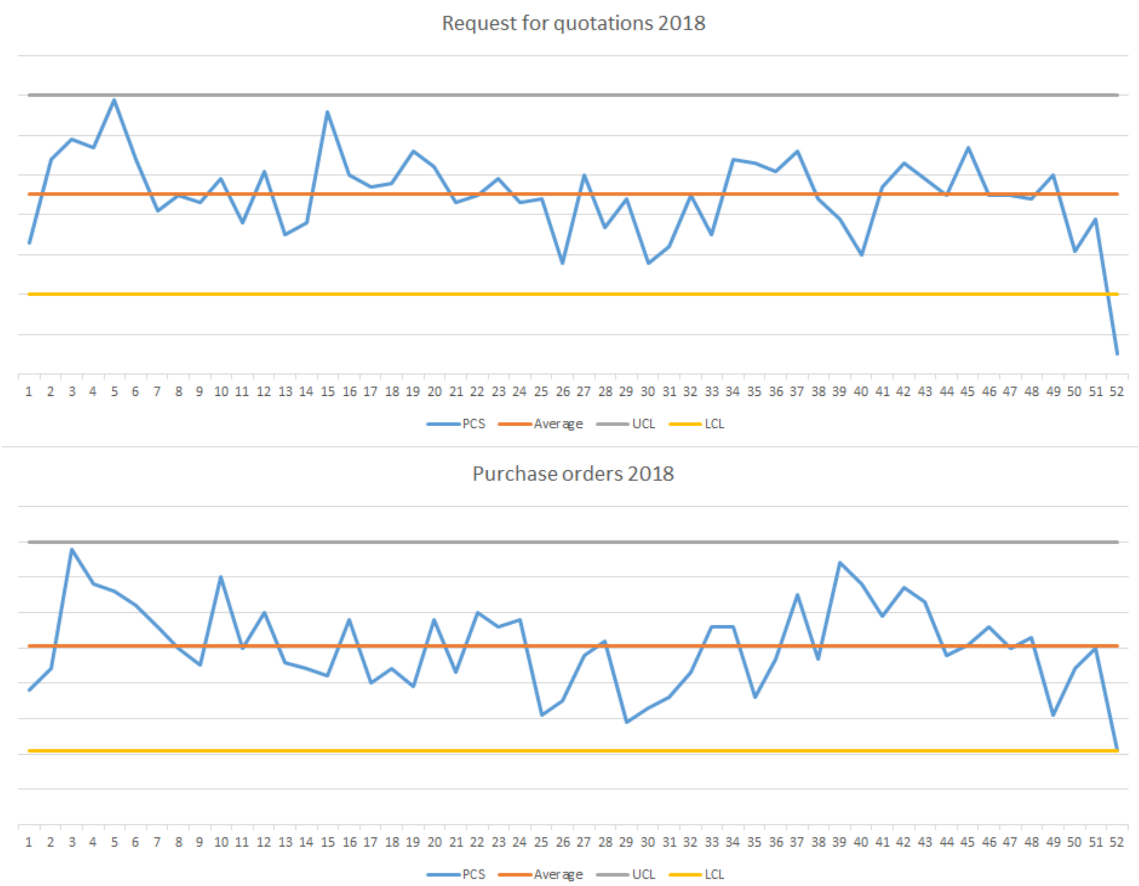

Figure 11. SPC-chart of arriving tasks, request for quotations and purchase orders in 2018.

Amount of tasks completed by the team per day was evaluated (figure 12). Again, data was combined as per weeks. Figure shows that predictable amount of tasks is completed weekly. In addition, the amount of completed tasks per day is on the same level than the demand. This way it would seem that customer should receive satisfactory service as enough tasks are answered weekly.

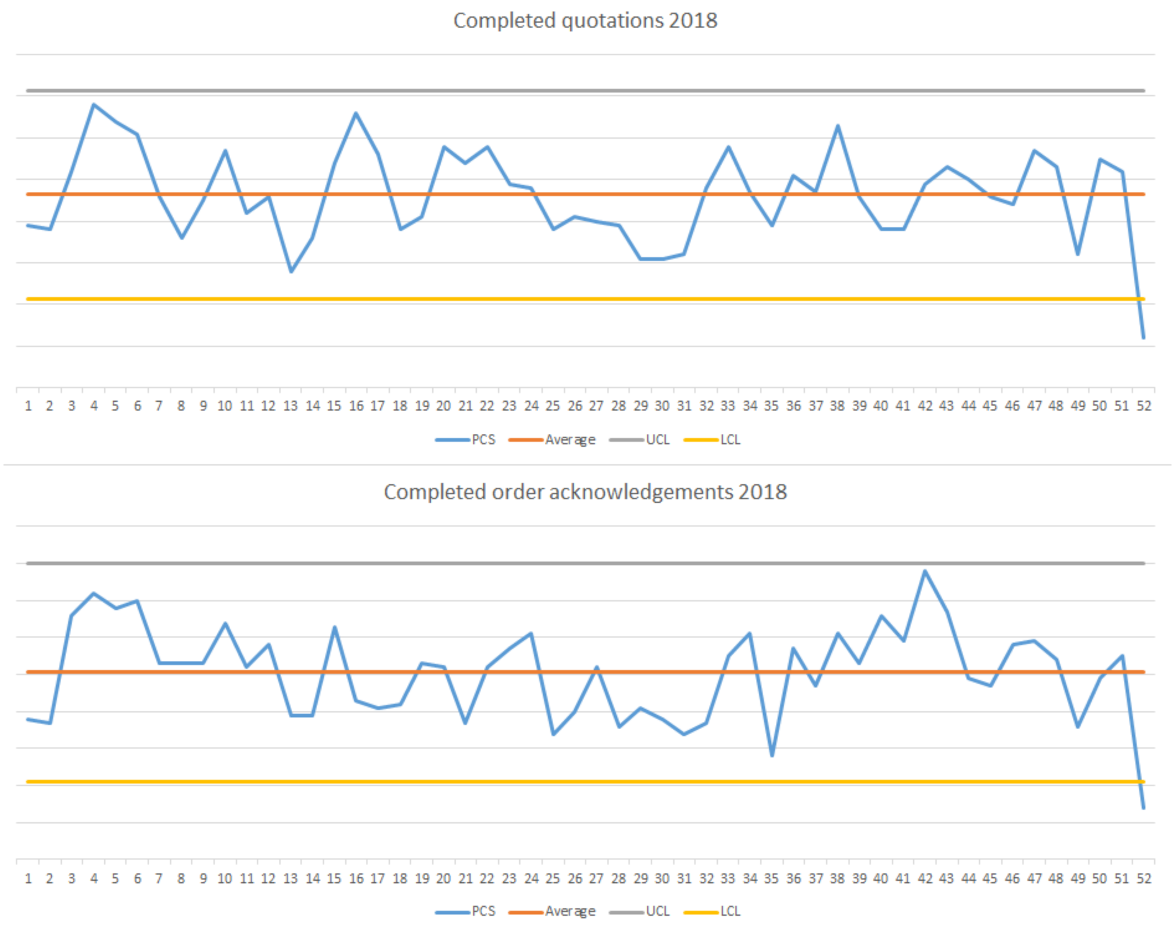

Figure 12. SPC-chart of completed tasks, request for quotations and purchase orders 2018.

Next, SPC-chart of lead-times for both, quotation and order processes containing each individual case is constructed. This is presented in figure 13. It can be seen that there are multiple “spikes” or assignable causes occurring. Up to 6% of the cases are crossing the upper control limit in both systems. Neither of the processes is stable and the customer is not receiving predictable service. Predictable demand from the customer turns into unpredictable lead-times in the opening phase of the process. Besides the length of the average lead-time of the processes, variation on when the customer is answered is sure to be causing dissatisfaction amongst customers who are dealing with the spare part transactions.

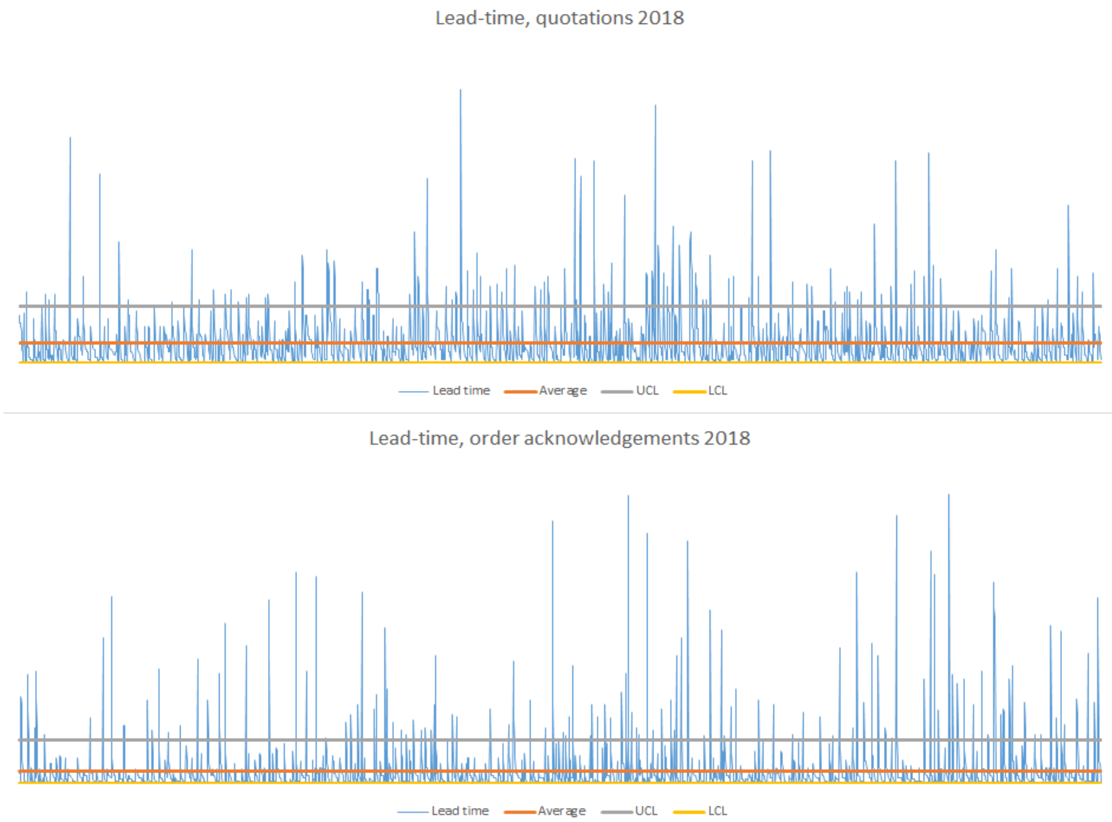

Figure 13. SPC-chart of lead-times, quotation and order confirmation process 2018.

The latest, the SPC-chart of work-in-progress is presented in figure 14. The amount of WIP is not predictable either, which again can make the situation worse. According to Little's law, an increase in WIP increases lead-time. This theory can be seen in the graphs, as the highest spikes in lead-times are occurring at the same time with the highest values of the WIP chart. Especially the quotation process's lead-times suffer from an increase in work-in-progress.

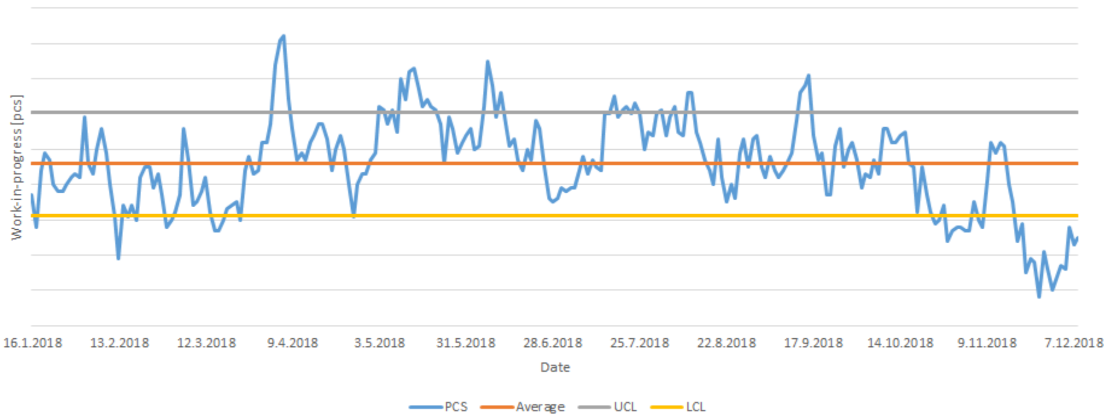

Figure 14. SPC-chart of work-in-progress 2018.

5.7 Urgent orders arriving to the sales organization

Based on the Gemba walks, it was noticed that urgent orders are arriving on a steady basis and affecting the prioritizing of the tasks (goes above anything else). To gain objective insights on the number of urgent cases arriving at the team, data was gathered from two separate weeks by the author. Weeks 43 of 2018 and week 7 of 2019 were chosen as a random sample from location A. As each purchase order and RFQ send by the customer are instructed to be saved in SAP attachments by the sales team, original e-mails of each case could be read. This email is the task description received by the sales personnel. If the original email or message exchange that followed contained some mention of urgency, sudden need, machine breakage, upcoming shutdown, etc. case was considered urgent. If the message contained no mentioning of such indicators, the case was considered as normal or not urgent.

Based on the events of two separate weeks, figure 15 could be constructed. It can be seen that the amount of urgency varies in these random samples but is at the same magnitude. A rough estimate could be made, that 10-20% of the cases (quotations and purchase orders) arriving at the sales team are urgent for the customer at any given week. Accurate data from multiple weeks is not reasonable to be acquired, as in each case, email has to be read in order to know the urgency level.

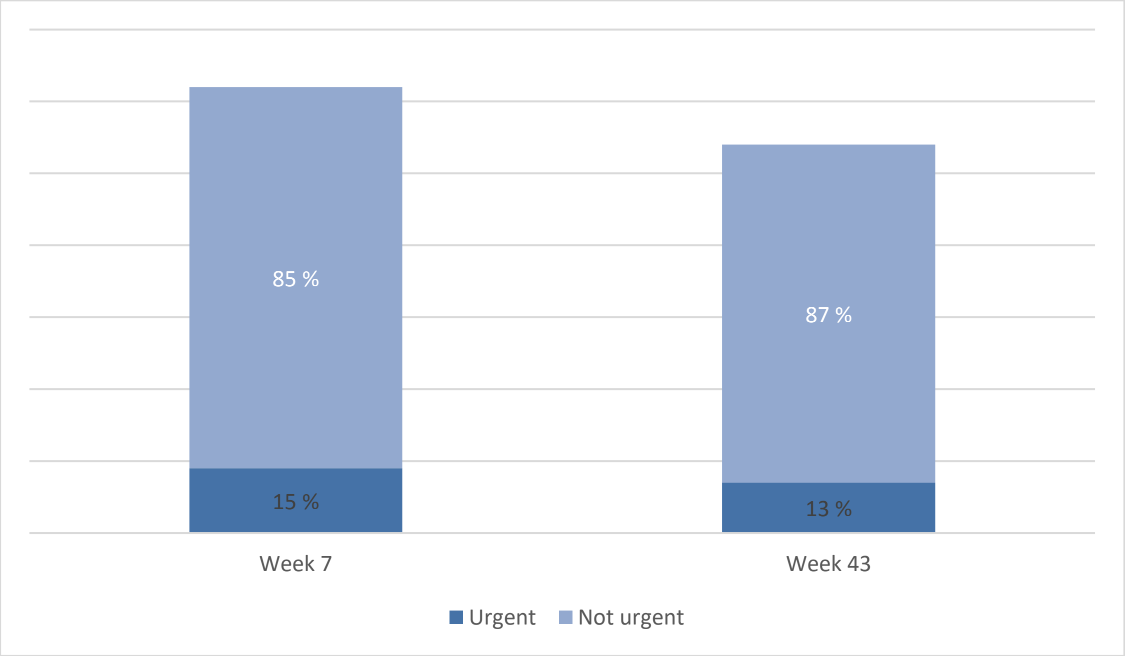

Figure 15. Amount of urgent and not urgent cases in week 7 of 2019 and week 43 of 2018.

5.8 Root cause analysis of long response times

As stated in the previous chapter, the bottleneck of the system is located in the quotation process. This part was also highlighted in the customer satisfaction survey, which is the second most challenging part in doing spare part business with case company. Thus, it requires a review that is more detailed. Data was gathered from interviews, Gemba walks with sales team members and managers in three locations to find out, what are the most troubling areas in quotation and sales work. These causes are eventually resulting in long response times. Then, the Ishikawa diagram was constructed to visualize the causes and effects of the work phase (figure 16). Root causes were gathered under six different categories and these are presented in more detail below. It can be seen, that long response times are the sum of multiple factors and are affected by three stakeholders: sales personnel, customer and supplier.

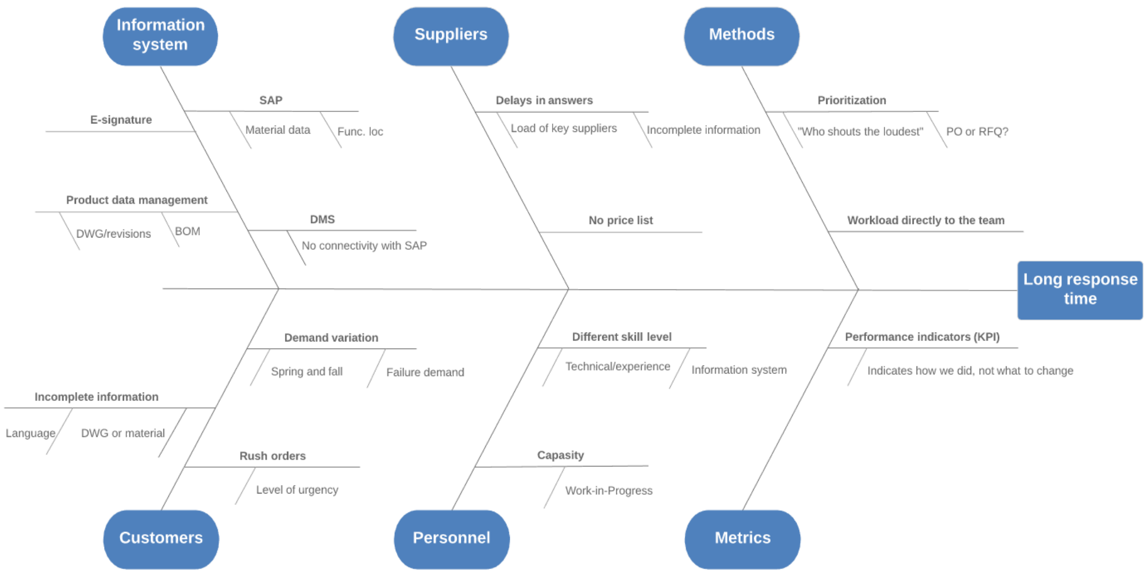

Figure 16. Ishikawa diagram on the problem “long response times”.

Under the class information systems, product data management causes major difficulties. Drawings are spread up to ten different locations (microfilms, papers, servers, software, etc.). Looking for the correct drawing is time-consuming work for sales personnel and makes product identification a long process in the worst case. In addition, if drawings are revised during the years, it is hard to say whether the drawing found in the latest edition. There should be certain rules on where to save the data. Under the same issue, functional locations or material numbers are not always made in SAP. If so, these need to be created before the offer can be made, which causes long lead-time. Functional locations created in SAP are also not as detailed level as sales would hope.

To support a project working, separate DMS software is used. Here, all of the documentation for the project is stored (drawings, meeting notes, etc.). This software does not comply with SAP. The information or attachments are manually fed into both systems causing double bookings with only minor advantages for spare part sales. In addition, automated e-signatures are required in all of the sales created, which sales manager is approving. This system is sometimes not working, and approvers are asked to “press the button” to get on with sales.

Customer is also one cause of long lead times. Quotations are sent with incomplete information, which leads to additional searching work or possibly sales personnel to ask additional data (drawing, material, equipment number, etc.) to identify the product. If data has to be asked, days will be consumed. This is due to the work queue of sales personnel (unread emails etc.) and the queue of the purchaser. In addition, information, which comes from the case company’s own front offices, is incomplete. This leads to an even lengthier chain of re-work as queries are passed through the whole chain from customer to sales and back.

Customer demand is causing a varying load to the sales teams. This is due to the cyclic nature of the business (spring and autumn) and summer holidays. The nature of the business also creates rush orders from the customers. As expensive equipment breakages happen, such spare part requests need to be handled urgently. For the sales team, it is not always known what the actual level of urgency is. The customer might ask for rushing an order or quotation process, but does not always give specific information on when the items are truly needed.

To offer a product, price and delivery time needs to be obtained from a supplier in many cases. This is one-factor causing lead-time in the quoting process, as it goes from the case company’s sales personnel’s queue to the queue of the supplier. Top of this, some delays are caused by the loading level of key suppliers, which is used by multiple departments of the case company. For example, one supplier is used in both, spare part manufacturing and starting up of projects. When equipment start-up occurs, no one is manufacturing the spare parts or answering the quotations.

In addition, sales might, in turn, send incomplete information to suppliers, who are forced to ask for additional information. In location A, quotations from suppliers are mainly asked by the purchasing department, based on the "quotation package" prepared by the sales department. This adds up to the response times seen by the customer, as there is one more handoff and another queue (case company's purchaser) to wait for. In other locations, sales are mainly responsible for asking quotations from suppliers.

For the personnel of the case company, different skill levels occur in both experiences gained during the years and due to different backgrounds. A lot of the knowledge is accumulated to the experts, and it cannot be found from the systems. As it was mentioned, the drawings can be found from multiple different locations. There are some memory rules, on what is the correct place to start looking. This is especially troublesome for newcomers. Moreover, the utilization rate of the personnel can be rather high, especially during the peak seasons. This increases the work-in-progress, which again causes longer lead times for queries. The high utilization rate of personnel also causes side effects via increased stress levels of having to cope under large workloads.

The spare part sales personnel are prioritizing the customers' urgent cases above everything else. Those cases not being urgent ones are facing long lead-times due to other companies pushing in front of the queues. In different locations, different prioritization rules were found between order confirmations and quotations. Some prioritized quotations over order confirmations and another way around. In addition, the customers directly send the workload to the individual team members. As variation occurs, some might be in large workload in one week and someone else might be having a smaller load at the same time.

Currently, the performance of the system is measured from the response-time seen by the customer. As a meter, this is a good indicator of how we are doing and that there is room for improvement. What it does not tell, is that what we should improve and how.

5.9 Causes for long lead-times and late deliveries

Besides the previously presented causes behind long response times, customers are facing long-lead times and on many occasions, items are delivered late. Long lead-times are eventually caused by the length of the inner process and delivery times received from the suppliers. Out of these two, it is easier to modify the inner processes of the case company than it is to require vendors to deliver items faster.

According to the interviews, shipping is a major reason for delayed orders and it attracted the interest of the author. In figure 17, pie charts of location A are comparing how many days were left for shipping operation to work with and reach the promised delivery date. Dates being compared are the last operation of the warehouse, (packing) where responsibility transferred to shipping, and promised delivery date to the customer. It can be seen, that up to 21 % of the orders reaching the shipping department are already late or have to be handled during the same day. For the items, which delivered late as seen by the customer, up to 55 % are such cases where shipping did not have enough time. This means that the rest of the value stream consumes the days needed by the shipping. It again distorts the prioritizing of tasks in the shipping department, as 21 % of the cases are already late and have to be handled urgently, before anything else. This need for prioritizing late items causes delays and long lead-times for items shipment received with a sufficient amount of time.

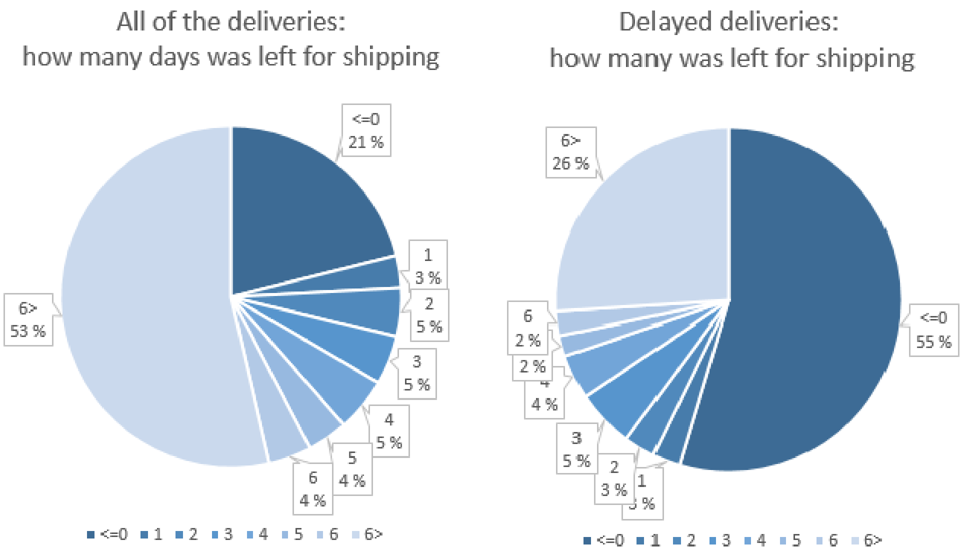

Figure 17. Location A: how many days was reserved for shipping, all of the orders (left) and delayed orders (right).

Reasons behind shipping department not having enough time can be caused by each individual step of the value stream. It can be either some of the following or all combined:

- Sales did not reserve enough time for the other departments,
- Purchasing of the items was delayed,
- Supplier could not deliver on time,
- Warehouse did not do the goods receipt on time,
- Sales did not do outbound on time,
- Warehouse did not pick and pack the items on time.

Thus it can be said, that there is huge amount of variables on why item was not delivered on time or why the lead-time was long. Root causes for all of these steps are not to be covered in this thesis, but the phenomenon of shipping not having enough time should be addressed in the case company as major factor on long lead-times and especially on-time delivery rates seen by the customer.

Out of these causes, sales departments are responsible on reserving enough time for the rest of the value stream and doing the outbound booking. Based on the discussions with sales teams, personnel are reserving on average 20% less time for the rest of the chain, than what the value stream map suggests and process is capable to produce. In addition, the outbound booking is consuming up to 15-20% of the time utilized in this delivery process.

6 RECOGNIZED DEVELOPMENT AREAS IN THE VALUE STREAM

Based on the current state analysis of the previous chapter, it can be said that the bottleneck of the process is in the sales department. According to the theory of constraints, development efforts are to be focused there. In this chapter, suggestions are given on what areas could be developed in the sales and quotation process.

6.1 Product data management

According to the interviews, the single most important factor on easy or hard transactions (variation) is the state of product data management of the item. As stated earlier, drawings have to be searched for up to ten different places. This is due the years of history, a new system replacing an old one and some company acquisitions along the way. In addition, the company is divided into service and product design/project departments, where the latter eventually determines where and how product-related data is managed. After the project is done, the latter department does not value up to date PDM as much as the service, who utilizes it on daily basis. For the service organization, it would be beneficial if the BOM's, drawings and material data would be easily available. There should be one place, where everything is stored and where everything can be found. This would decrease the variation of work required between different cases and thus decrease the lead-time. As the problem is wide, cross-departmental and strongly related to information technology, it is not reasonable to try to solve it in the scope of this thesis. Yet it is valuable to be aware of the issues in the PDM and these should be taken care of in the case company in the long run.

6.2 Required time for delivery process and outbound bookings

Based on the interviews on locations A and C it was discovered, that sales organizations are not reserving sufficient amount of time for the rest of the delivery chain. Average time currently required from purchasing to delivery can be calculated from the value stream map of delivery process (figure 18). It can be said, that time required for the rest of the value stream is 1,86x days on average (location A). To this, one has to add days for agreed delivery term from items arriving from suppliers and items shipped to customers. For free carrier (FCA), agreed delivery date is the date when products are ready to be shipped. Estimate depends of the location of the supplier, but for deliveries within Finland, this is approximately 2 to 3 days. For delivery at place (DAP), agreed delivery date is the date when goods are at case company's warehouse. In this case, days do not have to be added. Previously, sales teams have reserved 20% less time than what the process is capable to produce. This could be seen in the earlier presented figure 17, which states that shipping department is receiving orders, which are already late.

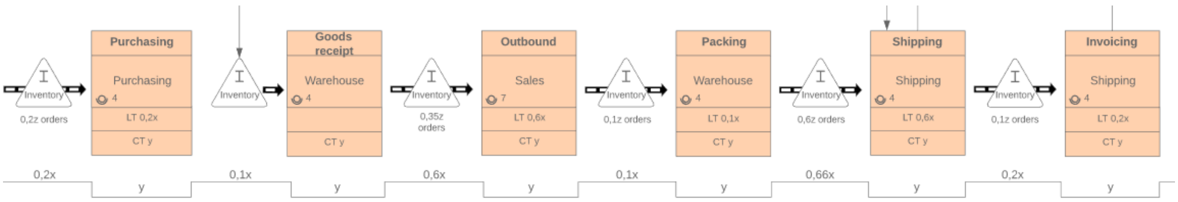

Figure 18. Time required for the delivery process.

One significant factor behind the long lead-times and variation is the outbound booking after the warehouse has received all of the items for an order. In the VSM of location A, it takes on average 0.6x days after all of the items are arrived and allow the items to be packed. This can be considered as waste of waiting, because the task itself takes only 5-10 minutes. By eliminating this step or alleviating the problem, up to 30% of the time used inner delivery process can be saved (from purchasing to invoicing) or excess days could be shifted where these are needed. In addition to this, variation of the rest of the delivery process is decreased. Based on the Kingman's formula, this should decrease the lead-times seen in warehouse and shipping.

The long lead-time in outbound booking is due to the fact, that sales personnel are not connected to the receiving of the goods and they do not get any information on the arrival of the items. Sometimes it happens that all of the items arrive, but sales forget to check the list of ready for outbound deliveries. If this is forgotten, items that could be shipped are waiting for the sales to press the button. This causes additional variation and unnecessary lead-time for the delivery. In addition, it consumes the days reserved for shipping and in the worst case it can be the cause for a delayed order.

This could be avoidable, by setting a daily routine for the sales team to check whether the items have arrived and outbound could be done. From the information technology- point of view, a solution could be a notification message. This would inform the sales engineer, that all of the items of the order have arrived and ready to be shipped. The feasibility of the latter was examined already during the thesis, but it might turn into email spamming machine. Therefore, a solution to this could be the first option. If outbound are done within a day of the arrival of the last part, the variation faced by the subsequent work phases is decreased. At the same time, the visibility for the shipping department is increased longer into the future, which allows better preparation for the tasks. The 0.6x days utilized in the outbound-phase could be used to decrease the lead-time or improve the on-time delivery performance.

6.3 Making the process predictable

Based on the SPC-chart viewing the lead-times of quotation and offering process, it can be said that these are not predictable for the customer. Before further improvements should be made, the process has to be stabilized. This means utilizing the SPC charts to filter out the routine variation of the process and focus on the cases, which exceeds the limits. This is an exceptional variation with the assignable cause behind it. These charts should then be utilized as a tool for continuous improvements for the process so, that over time variation decreases. (Wheeler 2000, p. 140). This would, in turn, lead to shorter and more predictable response times.

This means for example, that the sales team of location A could create a short (15 min) daily or weekly meeting, where SPC-charts are looked. If there is some event crossing the control limit, the team finds out what was the cause behind it. A short discussion is made within the meeting, on what could be done to prevent this from happening. Then responsible (e.g. sales manager) is assigned for this occasion and start systematic problem solving, for example with presented A3 problem-solving tool to prevent it. Timetable for the improvement project is determined and at the same time discussed on when we can return for this issue and spread the preventive idea. Table of open issues is created and presented in each meeting so, that each can see the status of the problem being solved and know that it is taken care of. In case there is no exceptional variation, no actions are needed in the meeting. (Torkkola 2016, p. 156.)

For example in figure 9, which was presented in the chapter 4.4.5 "Statistical process control", two spikes are occurring. After examining, the assignable cause behind the first spike was found to be in the area of incomplete substituting during the summer holidays.

The quotation was received at date x and sales personnel reacted to it by asking for a quotation from the supplier at date x. Supplier answered x with an offer after he was asked again to rush the offering process. The offer was sent to the customer on x, with the response time of y days. Now, the root cause of why substituting was not successful should be figured out. Ideas should be generated on substituting practices by the team so that events like this can be prevented in the future. The idea could be for example a hired summer trainee responsible for the sales area and with access to regular sales personnel's email box.

With these meetings and eventually by preventing assignable causes from happening, the process should stabilize over time into a predictable state. When this is achieved, the state of the process can be evaluated on whether it satisfies the needs of the customer or not. For quotation and sales processes, this means that customers would be pleased with the speed of the service, which is eventually seen from the customer satisfaction survey. If this is being the case, then continuous following of SPC-chart will be sufficient action and reactions should be made only if limits are crossed. If customers are not satisfied on the stable level of the process, Lean Six Sigma should be utilized to investigate the reasons behind the routine variation of the system and this should lead to even greater decrease the variation (Torkkola 2016, p. 171).

6.4 Prioritizing rule

One cause for predictable demand from the customers turning into unpredictable lead-times is that FIFO is not utilized as a main prioritizing rule. As it was stated earlier, the utilization of FIFO is a precondition for a predictable process. If not used, variation is created immediately at the opening stage of the process and the customer experiences unpredictable lead-times. Experts currently do prioritize according to their best evaluation in task selection. Main prioritizing rules are as follows:

1. "Who shouts the loudest", meaning the most urgent customer.
2. Purchase orders (Quotations in Location B)
3. Quotations (Purchase orders in Location B)

After the discussions with sales teams, it was noticed that beyond these three cases, "easy" quotations and sales orders might be buried under the other prioritizing rules. Easy items are defined by each person themselves, but these can be considered to be known (drawing, material number) and quite cheap and not in a rush. This prioritizing lengthens the lead-time for the customers on average and these should be the items that are passed through rather quickly.

As mentioned earlier, there are truly urgent cases for customers to be handled. These are caused by sudden breakdowns or shutdowns and are amounting between 10-20% of the cases. These have to be handled instantly, to satisfy the need of the customer. The workload from urgent cases could possibly be done by a separate processing line. This could contain one or two persons, who focus on all of the urgent cases arriving at the team. If no urgent cases are available, he/she can process the regular cases from the FIFO queue. 10-20% of the workload is in line with one person’s workload of the total demand of a year (each member of the team handles 10-20% of the total workload). This would free the rest of the team from urgent cases and enable pure FIFO prioritizing.

What should be considered is that if only one person is handling the urgent case processing line, it could become overwhelming and response times would rise (utilization rate too high) as variation in demand occurs eventually. This would not be the desired situation for customers in need of urgent help. Flexible rules on when tasks are done by one person and when the task has to be forwarded to the next person should be considered. For example, if x amount of urgent cases arrive per day, tasks are forwarded to other defined person. Also, if x amount of urgent cases arrive per week, tasks are again forwarded. This should keep the utilization rate of process line low enough and response times at an acceptable level.

In order to succeed in FIFO, the workload should not be released directly to the team from various sources. It means that tasks from customers would be gathered into a separate queue before reaching the sales team. Then, one person responsible could read the cases through on a daily basis or a few times per day and sort these as urgent or not urgent. Cases are then released to the team according to the urgency and arrival date (FIFO). This queue system together with a real-time following of WIP would enable leveling of workloads. Tasks would not be transferred to the team members unless something is gotten out of the process. Some constant levels of WIP could be calculated for each person, for example, the maximum of eight open cases at a given time. Then, the focus cannot be divided into multiple open cases and old cases are finished. As presented earlier in the text, by decreasing the WIP of the system, lead-time should decrease. This way WIP is artificially kept in controlled limits in the team's perspective and the demand variation from the customers is waiting in the queue for available resources.

Another way to organize the FIFO line is similar than what it is now. Together with a separate sorting queue before the team, dedicated person sorts urgent and not urgent cases. Then the task is sent to the responsible sales engineer and if it is marked as urgent, it is taken under work past the queue. If no urgent cases are in the queue, the oldest not urgent case from the queue is taken, first-in-first-out. This way, sales personnel do not have to wonder what should be done next, you can just take the next one from the FIFO queue. In addition, each case does not need to be read by the team members in search of urgent cases, as these are separated already. Cases can be left unread until it is time to be handled according to FIFO. This prioritizing rule should be obeyed, and no cutting in the line should be made after the first sorting operation. By doing so, the variation decreases in the task starts, and needlessly long lead-times are eliminated from the "easy" cases.

6.5 Finishing of the tasks without re-starting

The mindset in the sales organization should be also turned away from multitasking. If a task is opened, efforts should be made that it can be finished at once. This way the need for re-opening tasks and mental set-up times to understand what the case was about can be reduced. By doing so, the capacity of the process is not consumed needlessly. As Torkkola states (2016, p. 52), people should start the finishing of tasks and end the starting of new ones.

There are many reasons why tasks cannot be finished at once. For example, rush-order might occur via phone call and focus is shifted, information from the customer is incomplete or the delivery date and price has to be asked from the supplier. Ideas supporting one-step finishing of tasks should be considered. Rush-orders should be directed or separated in a way that sales personnel can work peacefully on the matter they have at hand. This requires that workload and demand variation is not poured directly into the team. This could be organized together with FIFO-line presented earlier.

Discussions with the case company's own front offices and customers should be opened, stating that sales teams face problems with incomplete data and cannot complete their work easily without asking additional information. Ultimately, this serves the customer as well, because, with accurate data, no need for re-processing or e-mail rally is needed. Eventually, quotations can be made with shorter response times. If this does not motivate the end customers enough, at least the case company’s own personnel in front offices should be contacted and clarified on, what information the quotation processing requires. If certain data is not found in the RFQ from the original customer (material number, drawing number or old offer, etc.), it should not be forwarded to the sales team in Finland but back to the customer directly. Missing information should be considered as errors, which have to be decreased. These errors have a considerable effect on the utilization rate and again on lead-times.

Asking for delivery time and price from the vendor is made during the quotation process. This is one factor causing long response times. In many cases, sales engineers can also evaluate the needed information from SAP history data from the previous sales order. Currently, there is no detailed rule on when this practice can be utilized. The rule could be created to support the utilization of estimates, which again erases one work phase and supports the completion of tasks once started. It could be for example following:

- The product has been sold within two years with less than 2000 euros.
- Not made from rare materials.
- If it has been sold two years ago, add 7% to the price, if sold year ago, add 5%.
- Delivery time is estimated according to history and current situation in the economy (utilization rate of the machineries). Sales must mention in the quotation, that delivery time is tentative, which will be confirmed when purchased.
- Immediately when the estimate quotation is sent to the customer, a quotation is asked from the supplier.

Sales and purchasing should also clarify who is responsible for asking quotations from suppliers. In location A, sales prepare quotation documents (technical documents) and provide these to the sales department. In location B, sales personnel ask quotations directly by themselves. Location C is somewhere in between, where few sales personnel ask the quotation themselves and other forward questions to the purchasing department. From the lead-time point of view, sales teams should ask the quotations directly, as this removes a need for one work handoff between departments. This again decreases the probability of errors and lead-time in general. During the thesis it was discussed, that sales should ask easily quotable items themselves and send hard cases to purchasing. Easy cases being standard parts or items having prior history of purchases. In addition to the quoting process, price lists between companies should be evaluated and if possible, widen the scope from the current state. This could be done for both cases, in transactions between supplier and case company and between customer and case company.

For the customers, price lists would allow avoiding the timely quotation process completely, as prices are negotiated already. By doing this, the workload of the quotation process should decrease. The problem in this is the nature spare part business itself. For example, three years’ period and one large customer, items that were sold more than three times are only making up to 12% of the count of sold items. Meaning that a major part of the items cannot be efficiently taken under contract or price list, as they are sold rarely. Yet, if approximately 10% of the workload could be avoided, it should be taken into considerations. The effort of determining the correct prices and negotiating these with customers should be evaluated against the ease of transactions in 10% of cases.

7 DISCUSSIONS AND CONCLUSIONS

The objective of the thesis was to find out the most significant problems along the value stream and offer concrete solutions to alleviate the issues. Eventually, this should be achieved by answering the set research questions. Three questions were identified and these are answered along the study and summarized in the text below. The main conclusion of the work is, that the current bottleneck of the spare part business is located at the sales department, considering quotation, order and outbound processes. This is based on the longest lead-times and the largest amounts for work-in-progress. Long response time in the quotation process is affected by many reasons, the most significant ones being the level of product data management and waste of waiting. Other causes are presented earlier in the text. To alleviate problems, sales processes should be stabilized to a predictable level by decreasing variation. SPC-charts could be taken into use as a tool aiming towards this.

The first research question was; what is the current state of the value chain? The current state was evaluated with the help of interviews, Gemba walks and data analysis. Data was combined with a value stream map to construct a visual outlook of the process. Relations between work phases, lead-times and WIP's of each was drawn and problem area could be pointed out according to the theory of constraints (system contains one bottleneck). The most problematic area, in this case, was in the quotation process, as it was having the longest lead-time and largest amount of WIP. This is the main conclusion of the study and it is also supported by the customer satisfaction survey, stating that response times in sales are the second most troublesome area in doing business with the case company. Only long lead-times were found more troublesome amongst the customers. This is effected by the complete inner value chain and its performance.

The reasons behind long lead-times in quotation and order process were evaluated in more detail. Multiple causes behind these were written down during the Gemba walks and interviews with the sales experts. These are presented in the form of a fishbone diagram earlier in the text. Many types of waste occur among the sales process, the most significant being waste of waiting. In addition, SPC-charts were drawn from arriving demand, completed tasks, lead-times and work-in-progress. It can be stated that customers are not receiving predictable service.

The second research question was: how the found problems can be solved or alleviated? Based on the current state analysis, problems were identified. To efficiently improve from the current state, development focus should be narrowed to ideas having the greatest effect. Suggested ideas are presented in detail in previous chapter and combined in table 1. Suggestions are marked together with needed actions, benefits achievable and effort required. The three most significant ideas are marked as high benefit, which should be focused first. The first is product data management, which should help in everyday transactions and identifying the products. The second of the most important ideas is to start a daily routine of checking outbound-booking. This could possibly cut off up to 30% from the delivery process lead-time and 15% of the total lead-time of the value stream in location A and similar numbers on location C. In addition, it should decrease the variation faced by warehouse and shipping, again decreasing the lead-time in these functions. The third most important suggestion is to match the delivery date promised to the customer with current state VSM lead-times of the delivery process. This way, promises are more realistic and items can be shipped on time. Other suggestions can be considered to have a medium or low impact on the performance but could be considered after the three high benefit suggestions are facing progression.

Table 1. Suggested improvements, their benefits and required effort.

Suggestion	**Actions**	**Benefit**	**Effort**
Product data management. Actions should be done in order to ease the daily transactions.	Requires co-operation between design and service departments and possibly some IT solutions.	High	High
Outbound-bookings as a daily routine in teams. If not done, creates unnecessary variation and lead-time to the delivery process.	Daily routine started in the location C. Progress will be evaluated, to see whether process improved.	High	Low

Table 1 continues. Suggested improvements, their benefits and required effort.

Suggestion	Actions	Benefit	Effort
Reserving enough time for the rest of the value stream.	Process of specifying correct dates to SAP according to VSM was started in location C.	High	Low
Discussions with customers and especially front offices regarding **what information is needed** in successful quotation and ordering process.	Draft list regarding what is needed is being prepared at location B.	Medium	Medium
Utilizing SPC-charts, continuous development of the process. Recognize assignable causes and prevent these.	The concept will be prototyped in location C after completion of the thesis.	Medium	Medium
Price lists for volume material, payment and delivery terms to SAP. Eases the manual typing work.	Communications with IT on how to update SAP, gathering of the data.	Medium	Medium
FIFO, new processing line for urgent cases, limiting the possible work-in-progress and leveling of the tasks between persons.	Could be prototyped with few personnel.	Low	Medium
Changing the mindset into **finishing tasks** without need to re-starting. Supportive ideas such as price lists and price estimations.	Discussions with the sales team on how they are currently working and presenting new ideas.	Low	Low

The third research question was regarding on could lean methodology be utilized to achieve shorter lead-times in the process. Based on the study, lean-methodology is at its core, a strategy to achieve the objective of efficient flow of value. This provokes to re-think business strategy on what value the case company wants to create and how to compete against other companies. The company can be resource efficient (cost-efficient), flow efficient (customer service speed) or a compromise from somewhere between these two. The path towards flow efficient lean- organization and culture is proven rocky and requires a large amount of commitment and effort, causing up to 70-90% of the lean projects failing (Karjalainen 2011).

Yet, lean methods and tools could offer alleviation to long lead-times. Understanding of systems and the underlying factors of variation, utilization rate, errors and WIP behind long lead-times proves to be valuable knowledge. Value stream mapping proved to be a useful tool in visualizing the flow of the value as seen by the customer and pointing out problem areas, for example the outbound-booking. SPC-charts display the variation as it is and can be used to point out assignable causes. Together with lean problem-solving tools, a possible decrease in the variation can be achieved and the organization forwarded into the path of continuous improvements. Fishbone diagram was used to visualize causes-and-effects behind long-lead times and this could be done to all of the other parts in the organizations.

7.1 Reliability, validity and error analysis

In the case company, two previous studies have been conducted in the related field, one regarding the strategy of the spare part business and another warehousing of items. This thesis differs from these by going close to the operative level of the organization and the daily work. In the scientific community, some research has been done in the field of improving service processes together with lean in office. Yet these are not directly applicable to the case company as it has its own special traits.

Work has been conducted with qualitative and quantitative methods, as objectively as possible. A large part of the study is based on statistical research, which can be considered objective. Problems in the value stream were found with interviews, and these are always subjective as the viewpoints of the interviewee are transmitted. Thus, interviews were made in three locations to gain a wider set of data. An interesting point rising from interviews was that each location mentioned the urgency of the shipping department as one cause behind delayed deliveries. Objective data analysis, in turn, indicated that orders are often delayed before the shipping department can process those.

As for the quantitative parts, the study can be considered reliable. The amount of numerical data observed was counted in thousands. Lead-times, especially in quotation and sales process were varying greatly. This was partly due the differences in each individual case; some might be big project type upgrade and other one single item. Averages were suitable in the initial comparison of different operations, but for further analysis, the utilization of averages "hide" data and reasons behind variation should be considered. The analysis was done for sales department with SPC-chart as time series, which pointed out, that over 6% of the events are above 3-sigma (99.7%) control limits. If needed, the gathering of the data from each step of the process could be repeated and analyzed in a similar way. Reliability of the research was increased, as both, the customer satisfaction survey and VSM constructed pointed out that response times in the sales department is a problematic area. In the study, lead-times were utilized together with WIP as main meters of the value stream performance (WIP affecting to lead-time). Lead-time can be considered as a valid meter for this purpose, as it describes the situation well from the customer's point of view. It also enables a numerical comparison of the performances between operations and locations as seen in the value stream map.

The qualitative study consisted of a literature review and interviews. In the literature review, reliability was ensured by using scientific literature as source material. For the interviews in the sales organization, independent sources were utilized. Three different locations, which have their own ways of working, sales managers and their subordinates, were interviewed. The findings from the three locations were combined and it was noticed, that similar problems were faced in each, with some unique traits in each. Solutions against these common problems were constructed as a result. With Gemba walks, basic knowledge on how work is actually made in each department was gained. This way, conclusions made are corresponding to the real state of the process.

Even with great care during the research, errors occur. The data used in the analysis was gathered from SAP by using multiple different transactions. Then, different dates were combined based on a common factor, such as order number or quotation number. Errors are prone to happen when thousands of rows are combined this way, as not all of it can be inspected. In addition to this, the reliability of the whole data analysis is based on the quality of the source data, which is known to contain flaws. Employees in different departments have to manually insert certain dates to SAP. These practices have been on the frame at the case company during the previous year, so the quality of the data has been improved. Still, sometimes dates are filled in wrongly by mistake or simply forgotten to fill completely. The manual inspection of these would have been a massive task, and it was done to some degree. Some of the missing data were filtered out from the study, as it cannot be compared properly. For data analysis, inbound deliveries (deliveries not going via the case company's warehouse) could not be taken into consideration at all. This is due to difficulties faced in obtaining data from SAP. It left 34% of the deliveries beyond the scope of analysis. Yet it can be said from the data analysis, that sufficient accuracy was achieved.

7.2 Scientific value, concrete applications and further development

For the scientific community, this thesis produced guidelines for evaluating service processes in practice. The idea and similar analysis done in the thesis could be generalized into other business processes doing transactional work. If one were to commit similar analysis, problems to be found would be different each case, but utilized tools should be universal.

New knowledge was generated for the case company from the state of the spare part business because of the study. A value stream map with numerical values included provides a basis for discussions between the departments. Responsibilities for each department can be clarified and ideas on what the next work phase requires to do their tasks can be shared. At the same time, the performance of the parties can be pointed out numerically, which moves the discussion away from subjective opinions. Positions in the value stream are pointed out and at the same time, everyone's effect on serving customers is seen. Data also pointed out the issues faced by the shipping department. Across the departments, thought was that the shipping department is under too much work and cannot ship products on time. Now it can be said, that other departments consume the days reserved for shipping, thus items being late. In addition to shipping, data on delayed outbound bookings were brought to attention. The case company was also provided with ideas possibly improving from the current state. Problems faced by the sales team were written up and can be addressed in the future.

For further development, suggested improvements in table 1 presented earlier could be considered and actions taken towards realizing these. The first steps should be about the high benefit improvements regarding PDM, outbound and reserving enough time for the delivery process. After this, continuous development with SPC- charts together with A3-problem-solving could be started in the sales department. Then, some version of FIFO prioritizing together with sorting of urgent cases and leveling of workload could be tested. Only after the testing period, it could be examined from lead-times, whether the given ideas were improvements or not.

Long delivery times were the most problematic area amongst the customers. Research that is more detailed should be made in the value stream subsequent to the sales department. As it was shown, 50% of the inner process’s lead-time is generated in this area. It has also a major contribution to the on-time delivery performance of the products, as it was shown in this research. Time reserved for the shipping department is consumed by the earlier stages of the process. Variation in purchasing, supplier delivering items, warehousing, and outbound bookings could be analyzed and decreased with presented methods. One significant founding was that outbound-booking takes up to 0,6x days, being 10-15% of the total value chain from quotation to delivery. Actual time required doing the task is somewhere between 5-15 minutes. By improving the way outbound is checked, preferably on daily basis, 10-15% saving in the process could be realized via shortened delivery times or improved on-time performance.

Then, the inbound delivery process should be evaluated. As it was stated, 33% of the deliveries are shipped from supplier to customer directly. This was not considered in this thesis due to difficulties obtaining data. There is no numerical information of how efficiently this process works. Yet this area contains the potential in decreasing the total lead-time faced by the customer. The inner shipping process of the case company could be avoided and one excess transportation between supplier and case company is eliminated, if inbound delivery is utilized. As a tradeoff, the customer could receive information about the true manufacturer of the product and cut the case company away from the spare part business.

As a whole, the thesis answered the research questions and reached its objective on finding significant problems of the value stream. It also offered some practical ideas for the case company on how to address these problems.

8 SUMMARY

The importance of the spare part business is more in the focus of the companies due to its ability to offer steady streams of income and possibilities for business growth. The speed and quality of the customer service can differentiate corporations in both, good and bad. In the case company, customer satisfaction surveys pointed out problems occurring in long delivery times of spare parts and response times to inquiries. The objective of this thesis was to evaluate the spare part business process of a case company and find out the most significant problems. Then, against these problems offer concrete solutions about how to improve. The thesis was done as a case study while using both qualitative and quantitative research methods.

The current state of the order-to-delivery chain was analyzed numerically based on the lead-times and the amount of work-in-progress. This analysis was done to all of the operations related to the spare part value chain containing sales, purchasing, warehousing, and shipping. In addition to numerical analysis, the author made Gemba walks to all of the departments and gained "basic training" from all of these. Understanding of how and why things are made was obtained. Based on the numerical data and Gemba walks, a value stream map was constructed to present the performance of the process and different relations between the operations. Lead-times were the longest and amount of WIP highest in the quotation process. According to the theory of constraints, development efforts should be focused on this area and to sales department in general, as these are sharing the same resources.

Unstructured interviews were made to three different sales locations, where the problems faced by the sales teams were discussed. Based on the interviews, root cause analysis utilizing a fishbone diagram was made. It pointed out multiple different causes to long response times in the quotation process, most significant being the state of product data management. At the same time, different kinds of wastes seen in the value stream were considered. SPC-charts were utilized to evaluate the number of tasks arriving in the teams, tasks completed in the teams, lead-times of each individual case, and amount of WIP. Based on this, it could be said that customers are not receiving predictable service, as lead-times vary greatly. Besides the quotation process, delay of 0.6x days was discovered from the value stream, in the outbound bookings. This counts up to 15% of the total quotation to delivery process, which could be eliminated. In addition, the delivery time promised from the sales department was not in line with the performance of the rest of the departments in the value stream.

Daily routine to check possibility to do the outbound booking was suggested to the sales teams. In this context, sales was informed about the time that rest of the value stream requires to perform their tasks. To develop further, processes should be stabilized. For this, a method of continuous development was presented. This contains utilizing SPC-charts to differentiate routine variation and exceptional variation. There is some assignable cause behind exceptional variation. By using A3 problem solving, these causes are to be prevented from re-occurring by the sales team. In addition, a new way of organizing and prioritizing the incoming tasks was presented. These ideas are to be tested in the case company after the completion of the thesis to see, whether improvements could be made based on the suggestions. The thesis reached its goal by analyzing thoroughly the current state of the spare part business and by suggesting improving actions.

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APPENDIX I

Questions for Gemba walks (Torkkola 2016, p.237-239).

1. **What are the problem areas of this service from the customer point of view?**
2. **Who is responsible for this service from the customer point of view (end to end)?**
3. **How work requests are received from the customer?**

   From where and in what frequency?
4. **Who schedules and prioritizes the work based on customer requests? What kind of prioritizing rules exists?**
5. **How fluent is the work?**

   Where the work comes to you?

   In what order you make the tasks?

   How is your work measured? How you know if you succeeded?

   How much there is WIP?
6. **How the tasks are moved after the prioritizing from one team to the next?**
7. **How the needed information is delivered to this work phase?**

   What kind of information you need?

   Where do you get this information?

   What and where do you save information?
8. **How would you develop this work phase?**

APPENDIX II

Example form for A3 problem solving.

Case company	A3 Problem solving Case title	Participants:	Date:
1. Recognize problem Why this is a problem? How it came up? Quantitative measures, figures and charts.	**5. Develop countermeasures** Develop countermeasures against the found root cause. This should solve the problem recognized in step 1. Utilize process charts, figures…		
2. Current state What has happened, narrow the point-of focus to reasonable size. Find out and describe problems, point out facts. If possible, present the problem visually (chart, figure, processchart). Make sure it is clear for everyone.	**6. Implementation plan** Who does? Small scale prototype. What is done? When is done? Gant chart as timetable What is expected to happen? How it is known, that improvement happened? (Eg. Lead-time decrease can be measured)		
3.Set a target for improvement Describe the goal so, that it can be measured (numerically if possible). Describe the gap between current state and future state, what and how much (eg. days in lead-time)	**7. Evaluate the results** Check whether improvements occurred. Done based on previous timetable.		
4. Root cause analysis Figure out the root cause for the problem. Utilize lean tools analysis, for example 5x-why or fishbone diagram. Point out the most probable cause.	**8. Standardize successful process** Should the tested idea be standardized for wider use? If it did not work, abandon the idea and return to step 5.		

APPENDIX III

Value stream map, current state.