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A case study of AS Spilka Industri

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Abstract

This paper is a co-operation project with AS Spilka Industri, a producer of hinges and fittings for windows. The focus of the thesis is on the business process of handling customer orders within this company and how it can be improved. The purpose of the project was to identify problems in the order process and investigate the root causes of these. Last, the intention was also to define and measure the delivery performance.

Lean and Six Sigma are introduced as the main theoretical concepts in this thesis, giving a philosophical perspective in the form of principles and goals as well as a practical perspective in the form of tools and techniques. They are both considered state-of-the-art methodologies and provide valuable tools for process improvement that are used in the analysis.

This thesis has applied a method for measuring lead times in business processes that required employee involvement. The collection of lead time data has been achieved by using lists where the people involved in the process have recorded lead times. The units of analysis have been limited to orders for standard products.

The analysis is divided into three parts. The first part concentrates on defining, describing and analysing the order process and the associated problems using Lean tools. The next part centres on value stream mapping and a method for how the current situation can be described and measured. Finally a metric and a tool for measuring delivery performance have been developed.

The paper focuses on two main problems in the order process: errors in deliveries and part deliveries. By using Lean tools the causes of these errors are explored further. The results from measuring of lead times have been divided into value adding and non-value adding time, and it shows that non-value adding waiting time stands for a large share of total time.

The analysis of the current order process leads to recommendations to Spilka on how they can reduce waste and improve flow in the order process.

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1. Introduction

This thesis focuses on improving business processes, and especially the order process. It is carried out as a case study of AS Spilka Industri. For simplicity, AS Spilka Industri will often be referred to as just Spilka in the remainder of the paper. The order process can be defined shortly as the sequence of activities that are associated with the filling of customer orders. The process will in the thesis be elaborated and analysed on the basis of theoretical concepts such as Lean and Six Sigma.

The paper is divided into six main chapters. The first chapter presents the company, AS Spilka Industri, and the research problem for the thesis. Chapter 2 focuses on the theoretical framework, giving an overview of the concepts of Lean and Six Sigma, before the research methodology and data collection methods are explained in chapter 3. The analysis is carried out in chapter 4, centring on the order process, value stream mapping and delivery performance. Chapter 5 presents a conclusion and recommendations to the company, while limitations of the study and further research are presented in chapter 6.

1.1. AS Spilka Industri

The thesis will take a closer look on AS Spilka Industri, a company located in Ålesund at the north-western coast of Norway. The company is now the world leading producer of hinges and fittings for the top hung fully reversible windows by H-Window. The next pages will give an introduction to the company. All information is retrieved from Spilka's web site or given to the authors by Spilka.

Spilka has a long history of production. They originally produced baby carriages and buggies under the name Spjelkavik Barnevognfabrikk AS, but after 15 years of operation, in 1948, they shifted to production of hinges and fittings for the local furniture industry. Shortly after this, the company was given its current name, AS Spilka. In 1958, the local inventor Harald Kvasnes developed the first fully reversible hinge for use on windows. This meant that windows could be opened and reversed, making it possible to clean the outer glass pane from inside. The window was named "Husmorvinduet" (Housewife's Window), later known as just "H-Vinduet" in Norwegian and "H-Window" in English. Harald Kvasnes and Spilka formed a partnership, and Spilka started to produce and sell the hinges.

Picture 1 Spilka Classic hinge (Spilka, 2011a)

During the years the hinge has been redesigned and improved, and more products have been developed. Since the 1980s all of Spilka's production has been window-related products. They can offer hinges and other components for top hung fully reversible windows (Classic), side hung fully reversible windows (Swing), sliding patio doors (Tango), and aluminium-clad top hung fully reversible windows (Opus). All hinges come in different sizes depending on the size of the window. Classic is now the name of the original hinge for the H-Window, which still is the main product for Spilka. The Classic hinge is shown in picture 1. Spilka owns two registered trademarks. In addition to H-Window they have developed Spilvent, which is a ventilator that can be used with most window types. Spilvent is shown in picture 2.

Picture 2 Spilvent (Spilka, 2011b)

Spilka's products are sold to customers in Norway as well as exported to other countries around the world. But the main market is in the United Kingdom and in Scandinavia. As of 2010 the company has an annual turnover of about NOK 120 million. Based on 2010 sales figures it can be seen that Spilka's sales are fairly equally distributed between domestic and international customers. 52 % of Spilka's customers are Norwegian, and the Norwegian customers stand for 52 % of the sales. The major customers are window producers, thus Spilka is operating in the business-to-business market. Good and long-term relationships with customers are of high importance for Spilka, and so they value timely and correct deliveries as well as high quality on the products.

The marketing and production department is located in the same facilities in Ålesund, and this is where the authors have visited to do research for this thesis. The production facilities in Ålesund consist of two production halls, each of them having a total production area of 1900 m^2. Additionally there is a branch office of the marketing department in the UK covering the Polish and Baltic markets.

Picture 3 **Spilka's marketing and production facility in Ålesund (Spilka, 2011c)**

Spilka also has a Research and Development (R&D) department with 5 employees, which is placed at a different location in Ålesund. This department is responsible for development and design, testing of prototypes, technical support and production control. More than 5% of the company's annual turnover is used to improve their existing products and also to develop new innovative products (Spilka, 2011d).

1.2. Research Problem

In this section of the thesis the research problem will be outlined and presented. First it will describe the background for the project, followed by an explanation of the research problem. Finally we have narrowed down the research problem into the formulation of research questions.

Spilka contacted Molde University College in September 2009. The company wanted students with a higher level of education to study activities in their company. They initially wanted the students to focus on the flow of goods, receiving inspections, packing and forwarding. It was decided by the company that one would not look into the production areas of the company in this project. Spilka has previously focused much on their production processes and made improvements in this area, and it was in their opinion that other areas of the company had better opportunities for improvement. In May 2010 an agreement was made between the authors and Spilka about a master thesis project for the spring semester of 2011.

In 2010 the company started a project on customer satisfaction. The objective of this project was to identify areas that the customers are not satisfied with. Spilka experiences that some of their customer orders cannot be delivered completely because not all products are available when the order must be sent, and that they therefore have to use part deliveries. Feedback from customers showed that one of the largest weaknesses is that the customer receives information too late when orders cannot be delivered as promised. Customers have not always been informed when products are missing from the shipment until delivery. Further Spilka thinks that the number of errors in deliveries is no longer satisfactory. We decided to use these observations as a basis for the further development of the research problem.

The problems with information and errors in deliveries that Spilka has recognized are parts of business processes in the company. Monk and Wagner (2009, p. 3) define a business process as "*a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer*". This customer might be internal in terms of other business activities depending on the process or external in the form of a traditional customer that buys the product. Business processes cross functional areas in an organisation, such as sales and marketing, supply chain management, HR and accounting. Each functional area includes a number of business functions, which are activities that are performed under the functional areas. Supply chain management, for example, consists of purchasing, production, transportation and receiving goods (Monk and Wagner, 2009). All businesses consist of a number of business processes (Willoch, 2005).

The business process in Spilka that has been most affected by the problems mentioned above is the process of handling customer orders. When products are missing from the delivery there has been an error somewhere in the activities from the order was registered to the final ordered being shipped, and the customer is not satisfied. Therefore, the business process we will concentrate our research on is the order process. Willoch (2005) describes a process that he calls "filling of orders", which is similar to the one referred to as order process in this thesis. This process starts when the customer has a need for a product, and ends when the customer receives the product. Such a process exists in all businesses that produce or trade goods, and it typically crosses business functions such as sales and marketing, forecasting, production planning, inventory management, distribution etc. Other definitions (Samaranayake, 2009) also include pre-sales activities with the goal of giving price information to the customer. Such activities include sales calls and visits, and these are the first activities in the customer order process. Sales orders are created on basis of the price information given in the pre-sales activities. This is followed by other order process activities such as inventory sourcing (checking if the products needed are available), documents release, picking and packing, distribution planning and invoice creation and customer payment.

In this thesis we have used these explanations of the order process and its activities and defined it so that it suits the way the order process is performed at Spilka. First we will present a short definition of the order process here, and then it is going to be described in more detail under chapter 3 about the research methodology for the thesis. The order process can be defined as the sequence of activities that are associated with the filling of customer orders. It uses customer orders as input, and the output is the physical goods being shipped. The functional areas in Spilka that are involved in this process are the order department and the warehouse, and those are the functions that we intend to work with.

When solving a research problem it is important to define interesting research questions that should be answered. According to Yin (1994) the process of defining the research questions is probably the most important step to be taken in a research study. The process of determining the research questions requires much preparation, so that the questions are precise and significant for the topic.

In this study we want to identify problems that Spilka has in the order process, and find the root causes of these problems. Further we want to measure and analyse the problems to describe how they are doing today. By identifying the problems Spilka has in the order process, suggestions on how to improve the problems and the business process will be made. The aim is to find out how Spilka can improve their business processes, using the order process as a main focus. During the work with the project it was discovered that though Spilka has an increasing focus on improving customer satisfaction, they have not yet clearly defined delivery performance and how they wish to perform in this area. It was therefore decided to include this in the research problem in order to identify Spilka's meaning of the concept and to develop a metric that can be used later to see the development. These elements can be summed up in three research questions.

Research questions

- What problems can be identified as the main problems in the order process at AS Spilka Industri, and what are the root causes of these problems?

- How can the delivery performance be defined and measured?

- How can the business process at AS Spilka Industri be improved to remove waste and increase delivery performance?

2. Theoretical framework

In this chapter an outline of the relevant theories related to the research problem will be given. The first part presents the theoretical concept of Lean production. Here the main principles and the origin of Lean will be presented, followed by a description of the differences between Lean production and other production systems. Next there is an explanation of the elements in the Lean philosophy. Within Lean there are several tools and techniques, and this chapter will introduce some of them, including 5S, 4M, 5 whys, cause-and-effect diagrams and value stream mapping. The Six Sigma concept will also be described, followed by one of its main problem solving methodology, DMAIC. Finally the chapter will present a brief look at the relationship between Six Sigma and Lean.

Lean and Six Sigma are relevant for the project, since both are methodologies that provide tools for how to improve processes. They are used by many companies in various industries and are referred to as state-of-the-art methodologies for process improvement (Salah, Rahim and Carretero, 2010). Lean focuses on the elimination of waste and Six Sigma focuses on improving quality and efficiency.

2.1. Lean production

The term Lean production was introduced by John Krafcik, one of the researchers in the International Motor Vehicle Program (IMVP) (Womack, Jones and Roos, 2007). This was a research program initiated at the Massachusetts Institute of Technology (MIT) in 1985, aiming at making a survey of the car production industry worldwide. The study included companies and plants in 14 countries over a time period of 5 years. The term Lean became popular after it was used in the book *The Machine That Changed the World* by Womack, Jones and Roos, in which the findings of the research program were presented. This book thoroughly describes a Lean system, but there is no explicit definition of Lean production (Shah and Ward, 2007). Plenert (2007) states that the concept of Lean has had many names, including Toyota Production System, Just in Time, Pull Manufacturing and Total Quality Management. Further he claims that Lean today is a collection of tools and methodologies, and when working with Lean improvement it is essential to establish a mix of appropriate tools in order to achieve the organisation’s objectives. One definition of Lean may be this from the Lean consulting company MainStream Management, quoted in Plenert (2007, p. 146):

> *"Lean is a systematic approach that focuses the entire enterprise on continuously improving quality, cost, delivery, and safety by seeking to eliminate waste, create flow, and increase the velocity of the system's ability to meet customer demand."*

Lean production can be described from two perspectives. There is a philosophical perspective that involves a way of thinking, in terms of guiding principles and overarching goals, and then there is a practical perspective that includes management practices, tools and techniques (Shah and Ward, 2007). Shah and Ward (2007, p. 791) propose the following definition in order to encompass many of the different elements of Lean:

> *"Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability"*

This variability that companies have to manage may be variability in supply, processing time, or demand.

2.1.1. Lean principles

There are five fundamental principles of Lean. These are described in Bicheno (2004).

- *Specify value from the point of view of the customer.* Products and processes should be designed based on the needs of the customers and not on what the company finds convenient.
- *Identify the value stream*. A value stream can be defined as a set of operations from raw material to the final customer. This should be mapped (see 2.3.5. about value stream mapping).
- *Flow.* The aim is to have a good flow in the process, so that there are no queues and delays. Especially a value-adding step should not be delayed by a non-value adding

step; in that case one should try to organise the process differently. Lean encourages the idea of “one piece flow” in operations. This means sending single parts or products or very small lots of them from one operation to another within a cell consisting of people, machines and workstations grouped closely together (in a processing sequence) (Liker, 2004).

- *Pull.* This principle involves producing only as a response to downstream demand, either from a final customer or from an internal customer. Lean aims at moving the point where push changes into pull further upstream in the process. If operations work at the demand rate of the final customer, overproduction, one of the seven wastes, can be avoided (see overview of the seven wastes in section 2.2.2.).
- *Perfection.* This can be achieved if the principles above are fulfilled. Perfection means zero waste.

These are goals within the Lean philosophy that may be impossible to fully achieve. However, they are part of a vision which one can work towards and with that improve by reducing waste.

2.1.2. Difference between mass production and Lean production

Lean was created as a term because it uses less than mass production: fewer people are needed, less manufacturing space, fewer machines and tools, less inventory, fewer defects and less time to develop new products. Lean has the goal of perfection, even if it probably will not be reached. Perfection implies falling costs, zero defects, zero inventories and high product variety (Womack, Jones and Roos, 2007).

The literature points out three main types of production systems: craft production, mass production, and Lean production (Womack, Jones and Roos, 2007 and Krafcik, 1988). Craft production appears first historically and is characterized by skilled workers that are involved in the production process of the whole product, not just a part of it. They use general-purpose tools and have very low production volumes (Womack, Jones and Roos, 2007). Two car manufacturers may illustrate the difference between mass production and Lean production. Often Ford is used as a typical example of a mass producer while Toyota is the typical example of a Lean producer. However in recent years the difference between the production systems of these two companies has decreased (Krafcik, 1988). Figure 1 below shows the three production systems in a matrix. Craft production achieved high differentiation, but the move to a mass production system enabled the industry to produce at a lower cost. Finally, Lean production seeks to achieve both high differentiation and low cost (The Automotive Consulting Group, 2011).

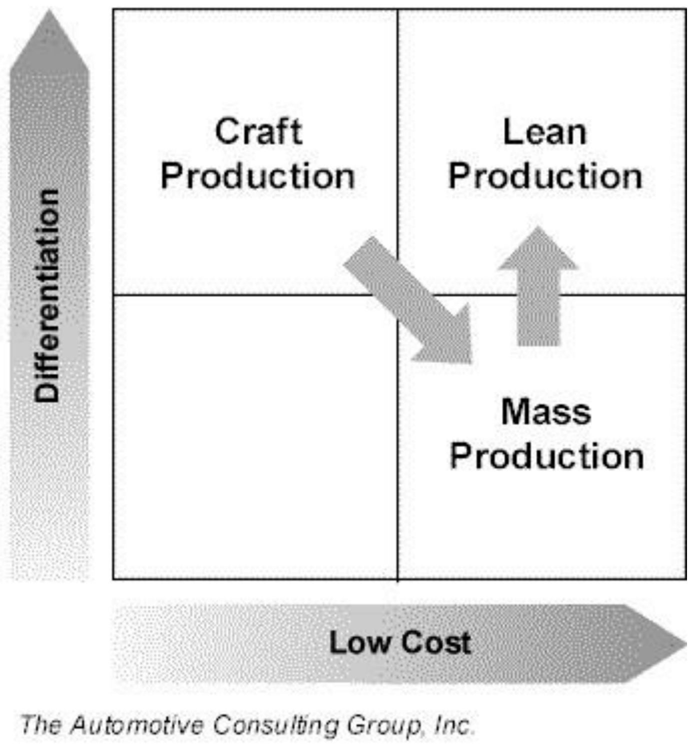

Figure 1 **The three production systems (The Automotive Consulting Group, 2011)**

Krafcik (1988) describes the difference between production systems using characteristics such as span of worker control, inventory levels, and size of repair areas.

Span of worker control:

In mass production, the workers have only one or two narrowly defined tasks to perform and they have little span of control over the finished product. The tasks are simple and of short duration so they are repeated several times a day. This standardization of tasks reduces the time needed for employee training. Toyota also used standardized work, but they made the employees responsible for standardizing the work and for continuously improving performance. They used the idea from craft production that workers should be skilled, combined it with the standardized work and assembly line of Ford's system and added team work as an important element (Krafcik 1988).

Part inventory levels:

The mass producers' way of achieving low production costs per unit is through economies of scale. This implies large batch sizes, which lead to high inventory levels, both of raw materials and components as well as work in process and finished parts (Womack, Jones and Roos, 2007). Lean production systems may be called high risk-high return systems. The inventory buffer is low, so if something goes wrong the production will come to a halt because there is no extra inventory or utility workers. The risk can however be minimized with well-trained workforce, responsive suppliers and good product designs. Systems that rely on high buffers have lower risk, but also lower potential for high performance (Krafcik, 1988).

Repair areas:

Mass production accepts that there might be a need for rework after the product is finished. Mistakes can be corrected before shipping the product to the customer, since it would be costly to stop the whole production line just because of a small error. Because mass production relies on large batch sizes, a defect will most likely not be discovered before many parts with the same defects are produced, thus the need for rework. Lean aims at discovering errors and defect in the process and immediately notifying those responsible so that the cause can be found and improved at once (Womack, Jones and Roos, 2007).

2.1.3. Toyota Production System

Lean is based on the Toyota Production System (TPS), a system developed by the leader of Toyota in the years after WWII, Eiji Toyoda, and his plant manager, Taiichi Ohno. After a tour of Ford's car manufacturing plant in the US, Toyoda realized that the Japanese market was too small to produce as many cars as Ford did, and they also did not have enough money to invest in as many machines. Ford used a large number of machines that each specialized in manufacturing one part in large batches, reducing costs per unit. Toyota therefore had to achieve higher productivity through a more flexible process (Liker, 2004). This was the beginning of Toyota Production System.

At the time of Eiji Toyoda's visit, Ford's plant Rouge was the world's largest and most efficient manufacturing facility. However, changeovers from producing one car model to producing another could take a long time. In 1927 Ford kept one of its plants closed for months when it switched from Model T to Model A (Womack, Jones and Roos, 2007). One of the methods that Ohno and Toyota decided to improve was the time it took to change dies on a machine. (Dies are used in a machine to press sheets of steel into a shape that is needed in the car.) Usually changing them took a full day, so large car producers did not do this very often. For Toyota that did not have that high production volume or many machines, the dies had to be changed more often. Ohno was eventually able to develop a technique to easily change the dies using only three minutes. In the process he also discovered that the cost per part of producing in small batches actually was lower than for producing in large batches. The main reasons for this were lower inventory costs and that defects were discovered almost immediately (Womack, Jones and Roos, 2007).

Another key aspect of the Toyota Production System is the focus on the employees. Toyota experienced some difficulties due to a depression in the late 1940s, and they had to discharge one fourth of their workforce. In this process however, Toyota made a deal with the remaining employees. First the president of Toyota, Kiichiro Toyoda, resigned to show responsibility for the problems. Second, the workers were guaranteed lifetime employment and salaries that increased with seniority. In return employees would work to help improve the company (Womack, Jones and Roos, 2007).

Some of the ideas behind TPS came from the US. One of those was the pull principle, inspired by the replenishment of items on shelves in American supermarkets. The pull principle has been explained as one of the Lean principles in section 2.1.1. TPS, or Lean, started with the Toyota company, but was soon spread to also include Toyota's many suppliers and dealers (Liker, 2004).

2.2. Elements of the Lean philosophy

2.2.1. Value and waste

There are different views on how value should be measured. Many agree however on the point that value has to be defined from the customer's point of view (Dennis, 2002). Plenert (2007, p. 285) defines value as "*A capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer*". Bicheno (2004) emphasizes that the future value also may be considered. This is what the future customers are willing to pay for, that the current customers do not value as much. However, this aspect is more relevant for research and development than for the current production.

The first question in TPS and Lean is: What is the value of the process to the customer? This applies to both internal and external customers. Internal customers are activities within the company that depends on the output of a previous process, while an external customer buys the product from the company. The steps of a process that do not add value from a customer point of view are waste or non-value adding (Liker, 2004). Activities that are typically considered value adding are those which transform raw materials or components into finished products. This includes assembling, forging raw materials and painting (Hines and Rich, 1997).

Lean production systems focus on elimination of waste, which is "*any activity for which the customer is not willing to pay*" (Dennis, 2002, p. 20). This is linked to value. Anything that does not add value is waste. Bicheno (2004, p. 14) claims that "*waste prevention is at least as important as waste elimination*". This means that a company should not only remove waste, but also focus on not adding any waste to a process.

The Japanese word for waste is muda. There are two types of muda: type 1 and type 2:

Type 1 muda: activities that do not create value but are necessary in the process.

Type 2 muda: activities that do not create value and should be eliminated.

(Bicheno, 2004)

Type 1 muda includes walking long distances to pick up parts, unpacking deliveries or moving a tool from one hand to the other. Activities in this category will most likely be difficult to eliminate without large changes to the system, and such changes might not be possible to achieve in the beginning. Examples of type 2 muda would be waiting time and double handling. The focus should be on those activities, seeking to eliminate them completely (Hines and Rich, 1997).

Waste is the converse of value, and it is essential to both enhance value and remove waste in order to improve. Figure 2 below shows how the steps of a process can be divided into value added activities and non value added activities. A process may often spend more time on non-value added activities, and here the focus should be on removing the unnecessary activities.

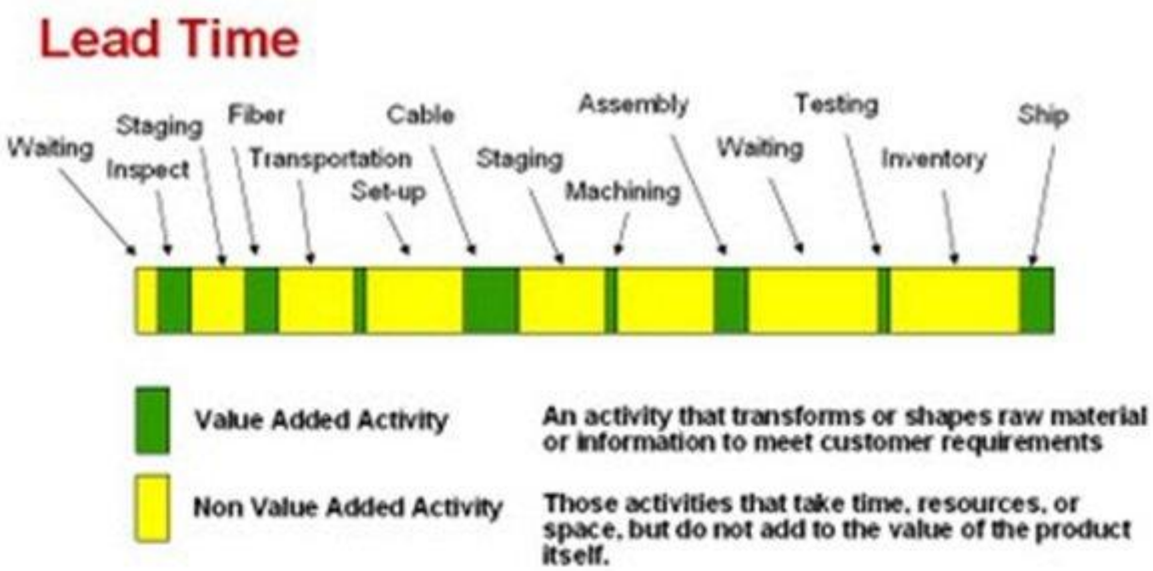

Figure 2 **Illustration of value added and non-value added activities (MacMahon, 2009)**

2.2.2. 7 wastes

Toyota has identified seven types of non-value adding waste, which are described in Bicheno (2004) and Liker (2004).

1. Overproduction.

Overproduction means producing too much or producing too early. Both create waste (Shingo, 1988). Overproduction is, according to Taiichi Ohno, also the most serious of the wastes as it is a cause of most of the other wastes. It leads to excess inventory, which consecutively causes unnecessary transport. Because of the high inventory levels and buffers, defects may not be discovered before at a late stage, and the motivation for workers to continuously improve activities might be reduced since the consequences of a machine breakdown are low when inventories are high.

2. Waiting (time on hand).

Waiting is an impediment to smooth flow. Workers may wait for work, or they might wait for a machine to finish, a tool to become available or a part to arrive. Either way it is considered waste, and the time should be spent doing something else, such as cleaning, checking or maintenance. Materials and operations may also be waiting. Materials waiting in queues and bottleneck operations waiting for work are also wastes and should be reduced.

3. Unnecessary transport or conveyance.

The movement of materials, work-in-process or finished products between processes or into or out of storage is considered a waste. It is however impossible to eliminate, so a company should aim at reducing it. An increasing number of transport and handling operations is increasing the likelihood of goods being damaged. Furthermore, the distance of transportation affects the communication negatively. The longer distance, the harder it is to receive feedback if the quality is poor.

4. Overprocessing or incorrect processing

Overprocessing is to process a product more than necessary in order to get the desired result. Incorrect processing refers to a process which inevitably leads to the production of defects. It is a result of not having the correct methods, tools, standards, product design and training.

5. Excess inventory

Keeping too much inventory is a waste that both costs money and hides other problems in the process. A well-known metaphor in Lean says that inventory is the water that hides problems in the form of rocks on the bottom of the river. Only by lowering the water level, the rocks will be exposed and needed to be solved. However, the rocks must be removed before the water level is lowered, or else the ships, representing shipments, will hit the rocks and sink (Baudin, 2004). The problems, or "rocks", may be defects and other quality problems, machine downtime, long setup times or late deliveries from suppliers. Excess inventory needs storage space which consequently increases storage costs. It also increases the risk of obsolescence, damages and delays.

6. Unnecessary movement

A non-optimal layout of a workstation leads to unnecessary movement. Workers having to walk to reach a tool or to get to another area is waste. So is looking for or stacking tools or parts. This is much about ergonomics of the workplace and also concerns health and safety.

7. Defects

Defects may be internal failure, causing scrap, rework or delay, or external failure, causing warranty, repairs, field service and maybe even a lost customer. This is a waste of handling, time and effort that could otherwise be used in value-added activities. The cost of a defect increases the longer it remains undetected; the first part with a defect may be inexpensive to correct or scrap, but if the part is connected to a finished product which is sold to a final customer, the cost will be much higher.

2.3. Lean tools

2.3.1. 5S

In the 1970s and 80`s the Americans started to visit Japanese plants to see how things worked there. What they saw were factories so clean that one could eat off the floor (Liker, 2004). Bicheno (2004) describes the five S system as a basic housekeeping system. It is also designed to create a visual workplace. Dennis (2002) describes this as a workplace which is self- explaining, self-ordering and self-improving. In this kind of workplace the employees can easily see if anything is out of order, and therefore easily correct it. Here are the five S`s as they are described by Liker (2004), Bicheno (2004) and Dennis (2002):

- *Sort (Seiri).* The first step is to go through all the items to classify which items are needed in the workplace. Items that are not needed in the workplace should be thrown out.
- *Set in order or Straighten (Seiton).* The next step is to locate the items that are used in the best place. Items should be located so that they reduce the waste (muda) of motion.
- *Shine (Seiso).* Continue to keep the workplace clean, always look for items that are out of place. This process also helps to inspect and look for failures.
- *Standardize (Seiketsu).* In this step companies need to develop a system and procedures that helps monitoring and maintaining the three first steps.
- *Sustain (Shitsuke).* In this last step everyone should participate to maintain and continue to improve the workplace.

As shown in figure 3 the five S’s create continuous improvements in the work environment. Liker (2004) explains that Lean systems use 5S to support a smooth flow to takt time. It can be used to make problems more visible, but it can also be part of the process of visual control of a well-planned Lean system.

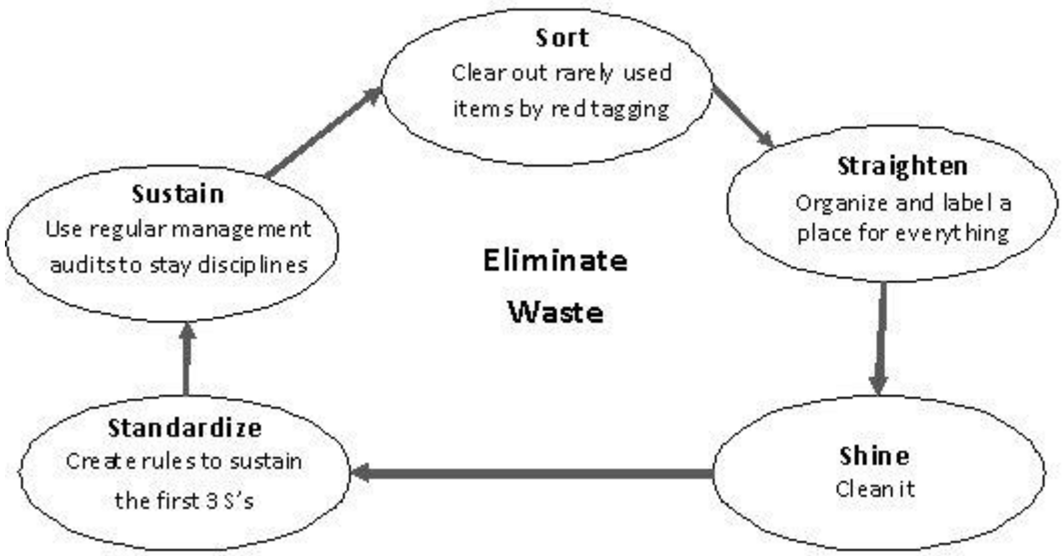

Figure 3 **the 5 S's (adapted from Liker, 2004)**

2.3.2. 4M

Another tool may be the 4M checklist (sometimes referred to as 5M, in which measurement is also part of the checklist). The four M's are:

- *Man*
- *Machine*
- *Material*
- *Method*
- *(Measurement)*

The 4 M's are the inputs to a process of creating a certain level of output that is desired by the customer, as depicted in figure 4. Under each M there are ten questions that can be asked in order to identify the root causes of the problem (Imai, 1986 and Dennis, 2002).

Today all businesses have the ability to hire the same workers, buy the same material and use the same machines as their competitors. According to Keller (2010) companies can have the ability to differentiate from their competitors through their methods. The methods that can be differentiated are designing and manufacturing the products, managing orders through customer service as well as selling and distributing. This is not done the same way in every business, so this may be unique for a particular company.

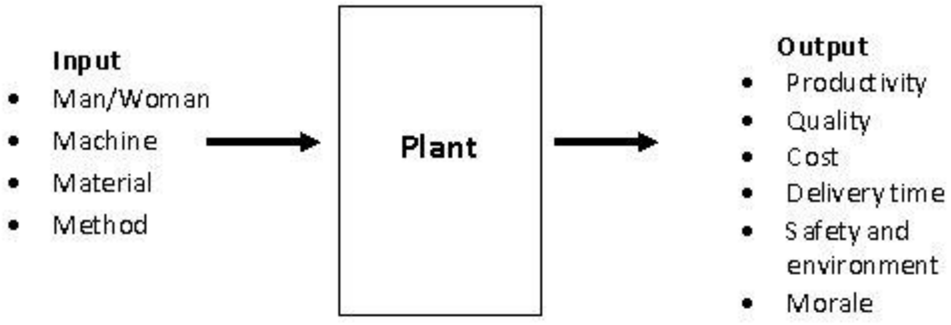

Figure 4 **A System View (adapted from Dennis, 2002)**

2.3.3. 5 whys

The “5 whys” is a method for discovering the root cause of a problem or a defect, so that one can improve the cause and keep the problem or defect from recurring (Womack, Jones and Roos, 2007). Solving root causes is fundamental to the Lean philosophy. Solving root causes means that the problem is solved at the root instead of at the superficial or immediately obvious levels (Bicheno, 2004).

The reason why the technique is called the “5 whys” is because the inventor, Toyota, experienced that “why” must be asked successively five times before the root cause is established (Bicheno, 2004).

According to Bicheno (2004) many people believe that the reason why the Japanese motor industry has great quality, reliability and productivity is because of the unrelenting seek for root causes.

2.3.4. Cause- and- Effect Diagram

A useful tool to identify and systematize root causes is the cause-and-effect diagram. Because of the shape of the diagram, see figure 5, it is also known as the fish bone diagram or Ishikawa diagram (Goldsby and Martichenko, 2005). Cause-and-effect diagrams can be used in brainstorming to examine factors that may be causes of the problem. By using the tool it can be easier to narrow down the root causes of the problems (Walton, 1986).

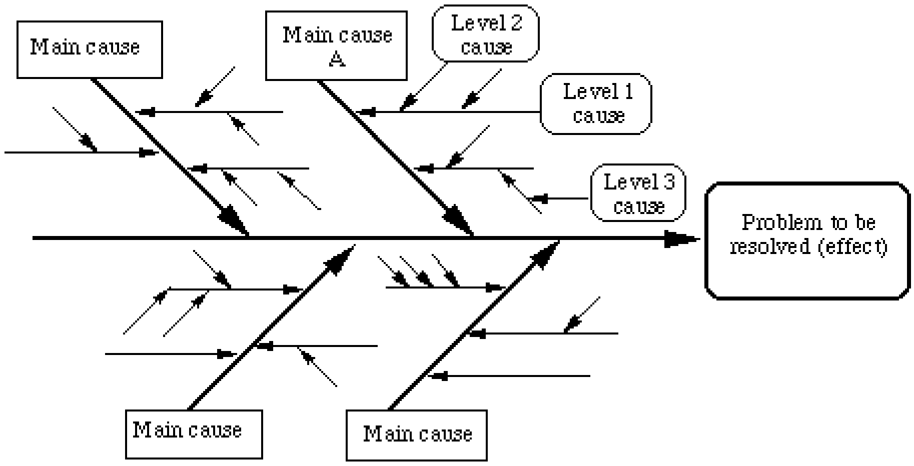

Figure 5 **Cause-and-effect diagram (Management Systems Inc, 2006)**

Walton (1986) mentions several benefits that can be obtained from cause-and-effect diagrams:

1. When making the diagram, discussions between the different members take place, hence people can learn from each other through discussing. The creation process can therefore be seen as educational.
2. Further the group is focused on the issue, which reduces complaints and irrelevant discussions.
3. Another benefit is that there is an active search for the cause.
4. Data must often be collected.
5. The cause-and-effect diagram can also show the level of understanding within the company. When the diagram is complex, it means that the workers are sophisticated about the process.
6. The diagram can be used for any problem.

The cause-and-effect diagram does not indicate what the right cause is, but it helps to develop educated guesses on focus measurements and finding the root causes (Pande and Holpp, 2002). By using the “5 whys” combined with a cause-and-effect diagram the root causes can be narrowed down easier. Also 4M can be used in the diagram to classify the causes.

2.3.5. Value stream mapping

Value stream mapping (VSM) is a mapping tool designed to enable management to:

- Visualise the process
- Point to problems
- Focus the direction of its Lean transformation

The purpose of value stream mapping is not only to visualise how the organisations acts today, but also how they should act in the future. An advantage of value stream mapping is that it shows the big picture, so that it is easier for the company to identify the critical areas. This is where the Lean efforts should be focused (Keyte and Locher, 2004).

Another purpose of value stream mapping is to identify opportunities for Lean improvement. The map includes all activities within a defined process as well as the inputs to and the outputs of the process. A value stream mapping process consists of four phases, as presented by Plenert (2007):

- Preparation
- Current state map
- Future state map
- Improvement plan

These are described in detail below.

<u>Preparation</u>

In the preparation phase one has to identify limits and ranges of the system that is to be studied further. This implies deciding which process has highest importance (i.e. largest impact on the business) and most problems. If the limits are too narrow, one may not include something that can be improved greatly and that should be included. On the other side, if the limits are too wide, it will be difficult to see the problems where the process could be improved.

Current state map

In this phase the goal is to draw a current state map describing the current situation in the company. The starting point here should be to define “value” from the customer’s point of view. Keyte and Locher (2004) also include that the main processes should be identified at this step. This is useful because it helps define the level of detail the process mapping should have. They also suggest collecting customer information such as who the customers are, their demands and their expectations of lead time.

The next step is to select appropriate key performance indicators (or process metrics). It is important to choose not too many, but just a few that are suited for the process that is being studied. Keyte and Locher (2004) emphasize that time (process time as well as lead time) always should be included as a process metric. Willoch (2005) states that a good process metrics portfolio should consist of metrics describing costs, quality and time.

Perhaps the most important step when drawing a current state map is to observe the process and perform a walk-through. This will be the basis for creating a value stream map containing specific icons and information about activities in the process. The reason for using standardized icons is that anyone who knows them can look at any map and be able to read and understand the information it contains. The value stream mapping icons used in this thesis are depicted in figure 6. By measuring the time it takes to perform the different activities as well as the time spent in between the activities, one can find the lead time of the process. The results of these measurements are necessary information when dividing all the activities into value-adding and non-value adding. The non-value adding time gives opportunities for improvement.

In this phase we should also calculate takt time, which is the time it should take to produce one unit in order to cover the customer need. The formula is:

$$\frac{Available\ Time}{Customer\ Demand}\ (for\ a\ particular\ period\ of\ time)$$

Available time can be measured in hours, minutes, seconds etc, while customer demand can be number of units. The current state map helps visualising the process so that it is easier to see where the company should focus its attention.

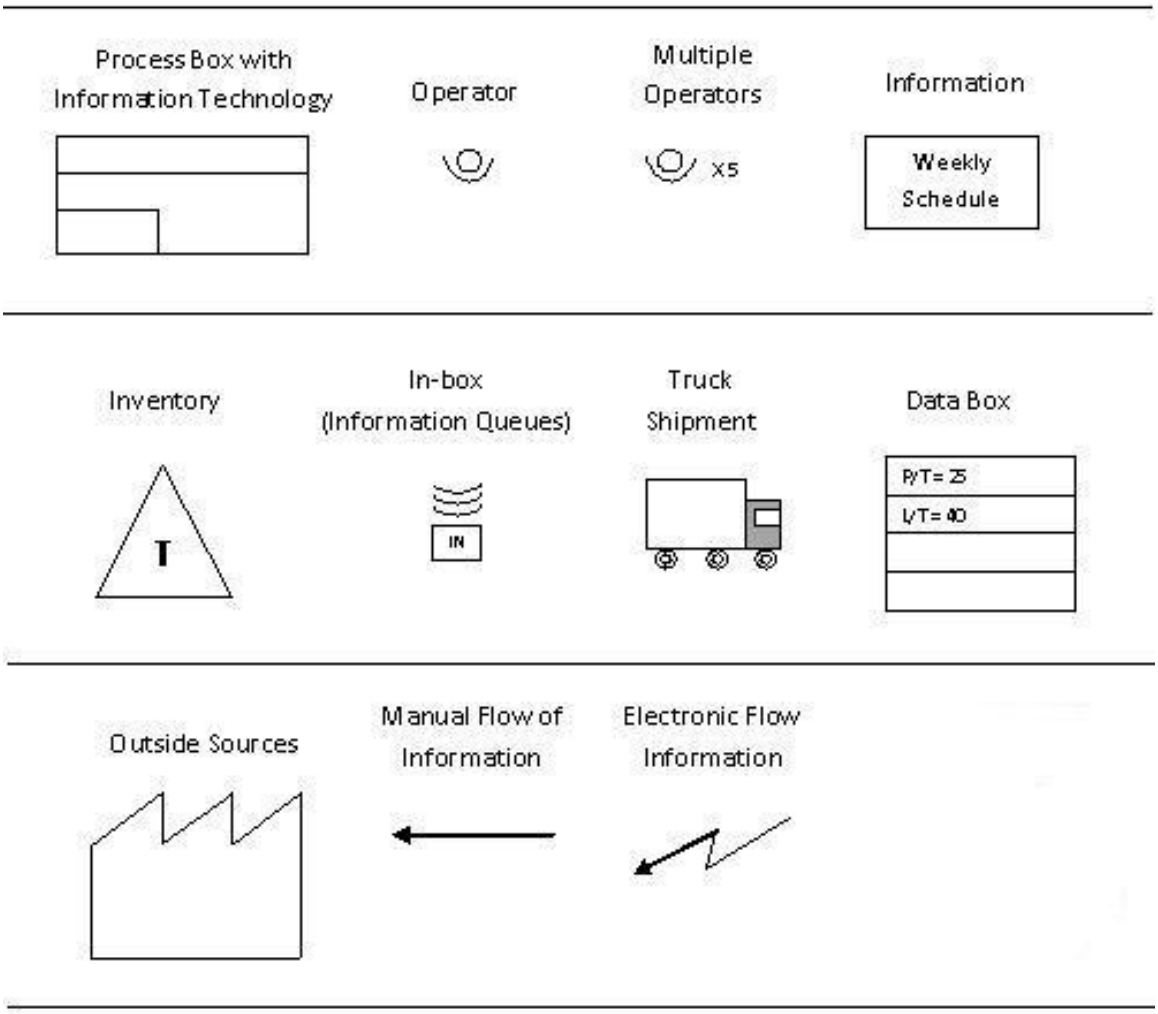

Figure 6 **Value Stream Mapping Icons (adapted from an overview in Keyte and Locher (2004))**

Future state map

The future state map can be considered as the goal for the results of the Lean improvement. It shows the ideal state that the company should try to achieve. However, since there in most cases are limited resources, the ideal state may not be achievable. So, the future state must be modified to illustrate an obtainable state. According to Keyte and Locher (2004) there will always be more than one possible future state VSM, so the ones who map should choose the alternative that is best suited to the company's goals and that are possible to achieve within a specific time frame (for example three to six months). By comparing the current state VSM and the future state VSM one can see the differences and the improvements that should be made in the process to get to the future state. This results in an improvement plan.

Improvement plan

Here an action item list of improvements should be developed. The items on the list could be classified and ranked according to criteria such as:

- How hard is it to implement the change?
- What is the impact of the change on the process under study?
- What is the cost?
- What is the time span for implementation of the change?
- How is the item related to top management's priorities for this Lean activity?

The ranked list is used to identify Lean "events", which are improvement actions that a company should initiate in order to achieve the desired future state (Plenert, 2007).

2.4. Six Sigma

The Six Sigma measurement standard in product variation goes back to the 1920s (Karlöf and Lövingsson, 2005). The Six Sigma theory originates from Motorola Inc. in the United States. The company faced threats from the Japanese electronics industry in the mid eighties, and therefore needed to make drastic changes to improve their quality levels (Linderman et. al. 2003).

Harry and Schroeder (2005, p. vii) define Six Sigma as *"a business process that allows companies to improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction".* This is about improving profitability, quality and efficiency. Six Sigma emphasizes the importance of having measurements, or metrics, on what is of value to the companies. It claims that what is not measured cannot be improved.

The Six Sigma term is related to the normal distribution. Here the values are centred around the mean and then the curve flattens out symmetrically on each side of the mean. Sigma, or the standard deviation, is the distance between the mean and the inflection point of the curve, and 68 % of all data is located within one sigma to the left of the mean and one sigma to the right of the mean. As the range is expanded to two sigma, three sigma and so on, a larger share of the data is covered. This is referred to as the sigma level; the larger the share of data in the distribution that are without defects, the higher the sigma level is. At a Six Sigma level, 99.9997 % of all output is without defects, and in this context a defect is any product that does not meet customer specifications (George, 2003).

A literature review made by Tjahjono et al. (2010) has identified four interpretations of Six Sigma that to some extent overlap. The first view describes Six Sigma as a set of statistical tools within quality management that facilitate process improvement. This interpretation aims to increase performance measures to Six Sigma level, which is called critical to quality (CTQ). According to Linderman et al. (2003) a key step in any Six Sigma improvement effort is to determine exactly what the customer requires and then to define defects in terms of their CTQ parameters. Having a Six Sigma level means that the process results in 3.4 or less defective parts per million (PPM). PPM is the main quality indicator within Six Sigma (Tjahjono et al., 2010).

The second view characterizes Six Sigma as an operational philosophy of management. The philosophy is flexible and can be applied to the whole supply chain, not only production. The third view defines Six Sigma as a business culture. In addition to the use of statistical techniques and tools, there is a need for top management commitment in order to achieve success. It is also described as an organised structure and a belief system which guides a company in decision making and uses specialists to reach strategic goals. The fourth view defines Six Sigma as an analysis methodology that uses scientific methods. It is described to be a continuous improvement methodology, with its DMAIC process (explained further in chapter 2.5.) similar to Deming's PDCA (plan, do, check, act) cycle. The Six Sigma methodology aims to improve business processes through reducing process variability and removing waste (Tjahjono et al., 2010).

According to Pande and Holpp (2002) there are three main areas that Six Sigma targets. First of all it targets to improve customer satisfaction. It also tries to reduce cycle times, and to reduce defects. By improving these areas companies have the ability to reduce business costs and also capture new markets. Further they will retain exciting customers, but also build up a reputation for their products and services.

There are two main methods within the Six Sigma theory: DMADV and DMAIC. DMADV stands for Define, Measure, Analyze, Design and Verify. The DMADV is an improvement system that focuses on new processes or products. The method can also be used when larger improvements are needed for existing processes or products. DMAIC stands for Define, Measure, Analyze, Improve and Control (Karlöef and Löevingsson, 2005). This method is used in this thesis and will be described further in the following section.

2.5. DMAIC

DMAIC is a method within the Six Sigma methodology, which stands for: Define, Measure, Analyze, Improve and Control. According to Karlöf and Lövingsson (2005) the aim of using the DMAIC method is to improve existing processes. It was General Electrics who introduced the four phases of measure, analyze, improve and control. Later the define phase was added (Salah, Rahim and Carretero, 2010). The stages are described further by Bicheno (2004), Pande and Holpp (2002), Goldsby and Marichenko (2005):

- ***Define:*** The main stage of the define stage is to define clearly and succinctly what the problem is. There are several sub stages within the define stage. The sub stages are to define the scope of the project, and what is important to the customer.
- ***Measure:*** How are we doing? The sub stages within the measure stage are to determine what to measure and how to measure it. Further the current performance should be

quantified and the improvement target should be estimated. There are three categories of measures in a process:

1. *Output or outcome:* the output is the result of the process. Here either the immediate result or the long term impacts are measured. A measurement for the immediate result can for example be deliveries, complaints or defects. Measuring the long term impacts can be profit or satisfaction.
2. *Process*: these measurements may help find out the causes of a problem. Examples can be training hours or costs per unit.
3. *Inputs:* inputs are things coming into the process which are changed into outputs. Measures can be order volume, on-time delivery and order type.

Measures that are used should be quantifiable and easy to measure. The measurements should also be robust, reliable and valid.

- *Analyze:* Find out what is wrong? The sub stages in the analysis will identify the causes of variation and defects. Further statistical evidence that causes are real should be provided in the analysis. One of the principles of using DMAIC is that all kinds of causes should be considered when solving the problem. It is important that the right type of tool is used when analyzing.

- *Improve:* Improve what is wrong. The improve stage involves determining the solution of the problem. Then the solutions should be installed, and finally statistical evidence should be provided to show that the solutions work.

- *Control:* Sustain the gain that is achieved. Here controls are put into place so that improvements are sustained over time. Further statistical evidence of sustainment should be provided.

Pande and Holpp (2002) list seven points that make DMAIC different or better than other methods:

1. *Measure the problem:* When using DMAIC the company cannot assume that they know what the problem is, they need to prove what the problem is with facts.

2. *Focus on the customer:* even if the company is trying to cut costs in a process the customer is important.
3. *Verify root cause:* root causes must be verified with facts and data.
4. *Break old habits:* real changes and results can take new creative solutions.
5. *Manage risks:* to get rid of problems tests are done to make the solutions more perfect.
6. *Measure results:* verify the real impact of solutions based on facts
7. *Sustain change:* making changes last is important

Figure 7 shows the five different stages within the DMAIC methods. According to Goldsby and Marichenko (2005) DMAIC is the backbone of Six Sigma. The method offers a map to improve projects from the conception to the completion.

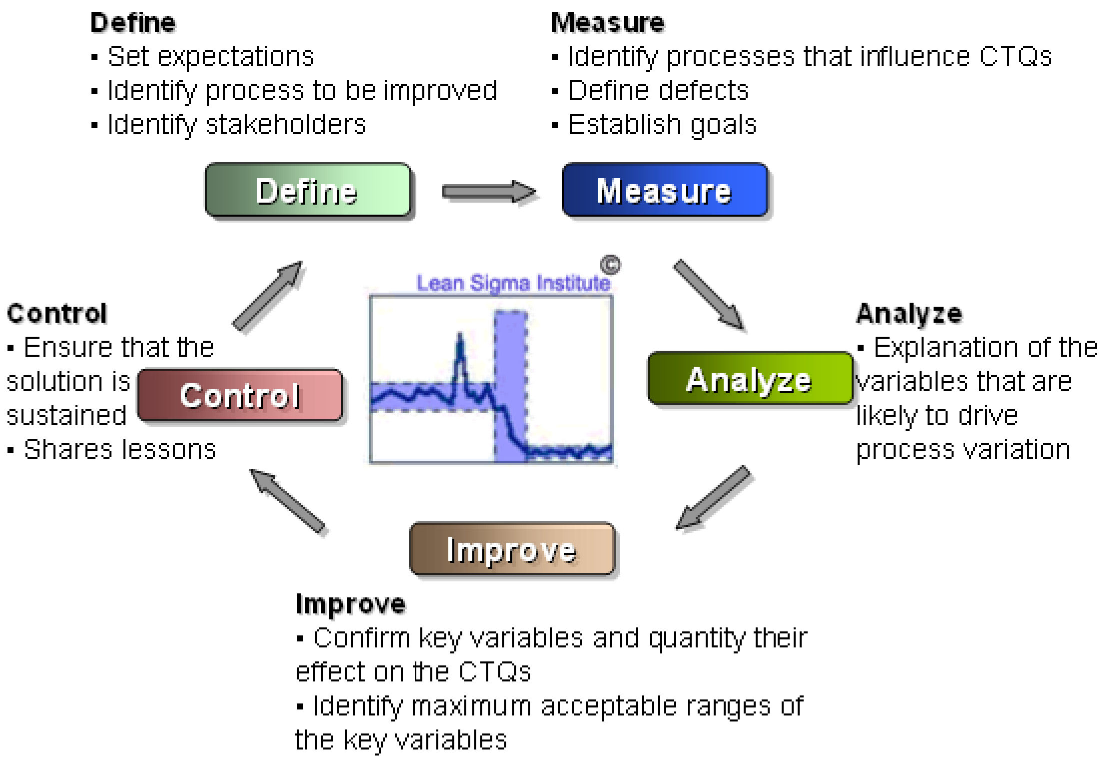

Figure 7 **DMAIC model (Lean Sigma institute, 2010)**

2.6. Lean and Six Sigma in service and office processes

The terms Lean and Six Sigma do not exclusively apply to manufacturing. The tools and principles may be applied to other areas of an organisation, for example service processes.

According to George (2003), service work may be harder to improve, due to a lack of documented standard processes that the workers are trained in. It may then be more difficult to identify areas that need to change and how they can be improved. Office work may be less visible than physical material flow in a manufacturing process. It is therefore necessary to make this more visible, and this can be solved by making process maps and charts.

Often in office work, there is a lack of data on queues and how much time it takes to perform the tasks. Service processes are also likely to have more variation than production processes since people perform the work and not machines. It is therefore important to include people in decisions about data collection, improvement ideas and plans, and to share the results with them. Doing this will reduce any resistance to change that some people may have, at the same time as employee creativity can contribute to the plans (George, 2003).

2.7. The relationship between Lean and Six Sigma

There are several similarities and differences between Lean and Six Sigma. Salah, Rahim and Carretero (2010) have identified 5 dimensions on which Six Sigma and Lean are the same and 26 dimensions on which they are different. The 5 similar dimensions are development, leadership, principles, features and staff roles. Both concepts have their roots in Total Quality Management (TQM), and they share some of the same objectives and principles as TQM. TQM is a management system with many similarities to Six Sigma and Lean. Six Sigma and Lean have been described in this chapter, but we are not going to explain the concept of TQM in depth here. For a comparison of TQM to Lean and Six Sigma, see Andersson, Eriksson and Torstensson (2006). Six Sigma and Lean both emphasize the importance of top management commitment in the leadership dimension. Finally they both employ a project management approach with the use of team leaders and the development of improvement plans.

Some of the differences between Lean and Six Sigma include definition, complexity, focus, tools and techniques, measures and results. Salah, Rahim and Carretero (2010) claim that

Lean is a simpler methodology than Six Sigma and that it may be easier to understand and implement. Further the focus of the two methodologies differ as Six Sigma focuses on statistical control and defects while Lean focuses on flow and speed of products and information. However they both focus on customer satisfaction and improved financial results. The tools of Six Sigma are analytical and statistical while Lean tools are mainly analytical, but at the same time some tools are common for both methodologies. Further the measures in Lean are primarily operational and often time-based while Six Sigma measures often are financial and cost-oriented. The results in the two concepts may also be different. Examples of results within Six Sigma are reduced number of defects and higher efficiency. Results within Lean may include improvement of quality, reduction of inventory, lead time and waste.

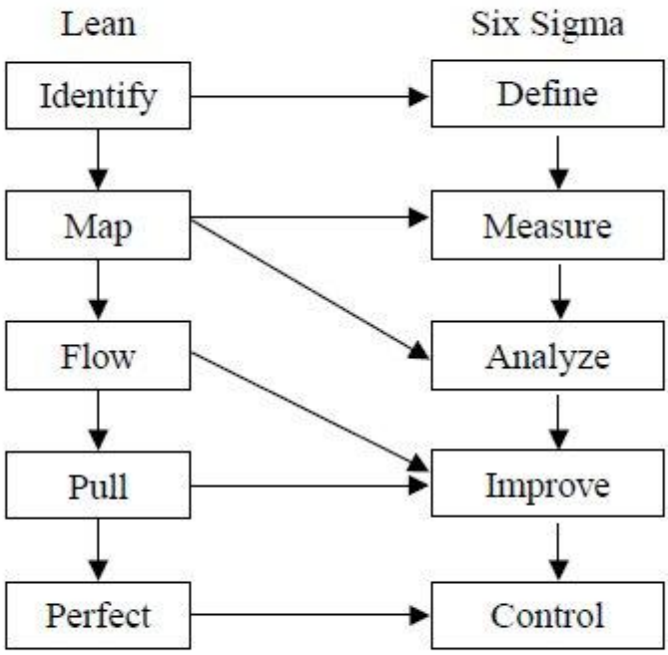

Figure 8 **The relationship between the five Lean principles and DMAIC (Salah, Rahim and Carretero, 2010)**

Figure 8 shows how Six Sigma and Lean are related with regards to the Lean principles and the DMAIC methodology. The first principle, which is to identify value from the customer's point of view, is also included in the define stage. Mapping of current processes includes measuring and collection of data which is the base for the analysis. In the improve stage efforts are being made to make the process flow better and to move towards a pull system. The perfection principle is related to the control stage where controls and procedures are introduced in order to maintain and develop further improvements (Salah, Rahim and Carretero, 2010).

According to George (2003), Lean primarily focuses on process speed, while Six Sigma primarily focuses on process quality. He claims that looking at Lean and Six Sigma as competing concepts is contradictive as one cannot achieve maximum speed without also improving quality and vice versa. Further it is argued that Lean and Six Sigma are complimentary concepts that work well together. There are gaps in the Lean methodologies which Six Sigma can fill while Lean covers areas that Six Sigma does not. Six Sigma emphasizes reduction of variation in processes and provides additional tools for statistical process control that Lean does not have. The key is to use Lean and Six Sigma simultaneously in order to remove waste and improve the process.

Today the complimentary relationship between Lean and Six Sigma is accepted, and a number of companies have initiated programs that integrate the two concepts. Such programs are called Lean Six Sigma. This new term is described as a methodology that aims at eliminating both waste and variability, and it uses the DMAIC method to achieve process improvement, customer satisfaction and improvement of financial results. Both methodologies can be regarded as tool boxes with some common tools. This gives the user a large variety of tools from which she can choose the most appropriate depending on the problem to be solved (Salah, Rahim and Carretero, 2010).

An integration of Lean and Six Sigma can use DMAIC as a structure since this is a well-known and understood methodology. For each of its different stages there are several Lean tools that can be used. Not all of the stages of DMAIC need to be equally important, depending on the problem to be solved one or more stages may have higher importance than others (Salah, Rahim and Carretero, 2010). George (2003) gives an overview of the many tools that can be used within each stage. Some of the measure tools that can contribute to description and prioritization of processes are value stream mapping, process cycle efficiency and Pareto charts. Pareto chart is a diagram which consists of bars representing the frequency of a cause or an element of a problem and a line representing the cumulative percentage of the same causes or problem elements. The bars are sorted in descending order. A Pareto chart is suitable to show whether there are a few causes that make up the largest part of the problem. Process cycle efficiency (PCE) is a critical metric for waste. This shows the share of value added time to the total lead time.

$$Process\ Cycle\ Efficiency = \frac{Value\ add\ Time}{Total\ Lead\ Time}$$

PCE of 10 % or less means that there are large opportunities for removing waste. Lockheed Martin, a major producer within the aerospace industry, estimated that 83 % of the activities from placing a purchase order until receiving the goods could be considered non-value adding. George (2003) also explains that most processes have process cycle efficiency less than 10 %.

The analyse tools include 5 whys and cause-and-effect diagrams. Both of these may be used to describe and explore cause-and-effect relationships.

Lean and Six Sigma are by some viewed as separate concepts and methodologies while it is recognized that they are similar in many ways. Others prefer to use an integration of the two, using the term Lean Six Sigma. Both Lean and Six Sigma are well-known methodologies to improve business processes.

3. Research methodology

This chapter will present the research methodology used in this project. The research design will be explained, followed by a description of the data collection methods and the types of data that were collected for the project.

3.1. Research design

Research design can be defined as "*a logical plan for getting from here to there, where here may be designed as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions*" (Yin, 2009, p. 26). The purpose of using research design is to avoid a situation where the evidences do not address the initial research questions.

According to Yin (2009) there are five main components of research design:

1. *Study questions*. These indicate what type of research that should be used in the study. It is important to formulate questions that are not already answered completely by someone else. Neither should they be too narrow.
2. *Study propositions*. A proposition is an addition to the study questions and the formulation of it helps deciding where to start the research.
3. *Unit of analysis*. This is the subject to be studied, whether it is a company or an individual person.
4. *Linking data to propositions and criteria for interpreting the findings*. This is done using tools and techniques on how to analyse the data.
5. *Criteria for interpreting a study's findings*. This could be statistical criteria, but it could also be about identifying and discussing other explanations that do not support your explanation for the results.

The methodologies used can be classified according to the type of data that is used, and also according to the type of analysis that is performed. The type of data can be divided into two categories, either it can be empirical or it can be modelled. Empirical data is often gathered for analysis from the real world, often via case studies and surveys. Also the data can be modelled, which means that either hypothetical or real world data is manipulated by a model (Ellram, 1996). How Ellram (1996) has chosen to classify the methodologies according to types of analysis and data can be viewed in table 1 below.

Table 1 Basic Research Design (Ellram, 1996)

		Types of Analysis*	
		Primarily Quantitative	Primarily Qualitative
Type of Data	Empirical	Survey data, secondary data, in conjunction with statistical analysis such as: factor analysis cluster analysis discriminant analysis	Case studies, participant observation, enthnography. Characterized by: limited statistical analysis, often non-parametric
	Modeling	• simulation • linear programming • mathematical programming • decision analysis	• simulation • role playing

The research design in this study can be classified as empirical, since the study is of a real life company. The empirical study uses primarily qualitative analysis through a case study of the company. According to Ellram (1996) qualitative results are often presented verbally to create an understanding of relationships or complex interactions. When analysing the company in this study, participant observations is also a type of methodologies that is used. The types of methodologies used will be described further in this section.

This thesis uses a case study method together with action research. These types of research design are described in more detail in chapter 3.1.1. and chapter 3.1.2.

3.1.1. Case study method

Yin (2009, p. 18) defines a case study as "*an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the* *boundaries between phenomenon and context are not clearly evident*". According to Ellram (1996), case studies may lead to both qualitative and quantitative results.

It is important that the case study does not only describe, but also facilitate understanding. There should be an educational message through explanation of the chosen aspect. According to Aitken and Marshall (2007) the author can write the case study more relaxed than a scientific report. Case studies use both qualitative and quantitative data to help understand the chosen aspect (Meredith, 1998).

Using case studies can have several advantages. In a case study an aspect is studied in its natural settings, and relevant theory generated from the understanding is gained through observing the actual practice. Also in a case study more meaningful questions of why instead of what and how are asked. This gives a better understanding of the nature and complexity of the complete aspect (Meredith, 1998).

On the other side using case studies can also have several disadvantages. In case studies direct observations are used. One disadvantage is that these are time consuming, and that one needs access to the phenomenon being studied. Also there is a need for multiple methods and tools, which can be both costly and time consuming (Meredith, 1998).

3.1.2. Action Research

In this thesis we have studied a real-life situation, and an appropriate research methodology for this is action research. Action research is an integration of research and action in several cycles of data collection, analysis and interpretation, planning and introduction of action strategies, and evaluation of these strategies through further data collection. The process continues in the same way into another cycle, and the series of cycles is stopped when someone decides to stop it, and then the final results may be seen and presented (Somekh, 2005). As more such action cycles are determined, new information will be discovered and new constraints will emerge (Coghlan and Brannick, 2010).

One main aspect of action research is the close co-operation between the researchers and the practitioners in a company who seek to solve a problem. The practitioners are participating in the research. According to Denscombe (2007), this gives a greater appreciation of, and respect for, the knowledge possessed by the practitioners. The relationship between researchers and practitioners may also provide the project with valuable knowledge about, and understanding of, the situation and the workplace. This is information that normally could be difficult to obtain with traditional researchers from outside (Somekh, 2005). In our work with this study we emphasize the importance of close co-operation with the practitioners. One of the authors participated in the company's operations during the summer, and we have received help from the employees and managers at Spilka throughout the whole process. The research has evolved continuously through discussions and co-operation with key persons in the company.

Action research applies the existing knowledge to the situation which is being studied. The aim is both to solve a practical problem and to build upon the existing knowledge through using data from the real-life situation in a particular field of study (Coghlan and Brannick, 2010 and Somekh, 2005). This is also the goal in our case as we have worked with Spilka to come up with solutions to practical problems as well as writing a thesis based on a theoretical framework.

One of the advantages of action research as a method, as described by Denscombe (2007), is that one solves a practical problem where the results of the research are transferred into practice. Also, the participation of practitioners in the research can "*democratize the research process*" (Denscombe, 2007, p. 131).

However, there are also some disadvantages. Using action research means that there will be some extra work for the practitioners, as they are to take part in the research. Further, the research is constrained by what is allowed and ethical in the workplace setting being studied. It is also more difficult to be impartial for the researcher in the approach to research (Denscombe, 2007).

3.2. Data collection

Data collection can be divided into two categories. The data can either be primary or secondary. Hox and Boeije (2005, p. 593) define primary data as *"data that are collected for a specific research problem at hand, using procedures that fit the research problem best."* Further Hox and Boeije (2005, p. 593) define secondary data as "*data originally collected for a different purpose and reused for another research question".*

Primary data can be classified as qualitative or quantitative data. Qualitative data involve understanding of the complexity and context of the research problem. The qualitative data often consist of text, while quantitative data are described numerically (Hox and Boeije, 2005). Table 2 presents a list of methods to collect both quantitative and qualitative primary data.

Table 2 **Primary Data (Hox and Boeije, 2005)**

	Solicited	*Spontaneous*
Quantitative	Experiment Interview survey Mail survey Structured diary Web survey	(Passive) observation Monitoring Administrative records (e.g., statistical records, databases, Internet archives)
Qualitative	Open interview Focus group Unstructured diary	(Participant) observation Existing records (e.g., ego-documents, images, sounds, news archives)

Yin (2009) identifies six sources of evidence that are most commonly used in case studies. None of the six sources have a complete advantage over the other sources. The six sources of evidence are:

- Documentation
- Archival records
- Interviews
- Direct observations
- Participant observation
- Physical artefacts

In this case study of Spilka Industri several of the six sources were used to gather information. The sources of evidence that are used will be presented briefly in this section before they will be described more in-depth later in this chapter.

The primary data collection in this research study has been done in several ways. First we started with participant observation. This observation was fairly unstructured to get a better understanding of the company, and took place by one of the authors who worked in the company for five weeks during the summer of 2010. During this observation period she tried to get an overview of the order process in the company, and to see how the warehouse workers handled orders. We also performed several casual observations to collect more data; this will be described under section 3.2.2. about direct observation. Further primary data were collected through interviews with warehouse and office personnel; this will also be described further under section 3.2.1. about interviews. Information was also gathered by asking the managers whenever we had questions.

When secondary data are used in research several problems may appear. First, it can be difficult to find data that can be useful for this particular research. Second, the researcher must be able to collect the data that she needs. Last it is important to be able to evaluate the quality of the retrieved data (Hox and Boeije, 2005). For this thesis we have received secondary data from the company, and these have been mainly quantitative. The quantitative data from the company were about annual sales, number of part deliveries, how many orders each customer ordered and how many deliveries each product had. This data originated from Navision, which is the ERP (Enterprise Resource Planning) system that Spilka uses. Further we also used data from a logbook of delivery errors that occurred from April to December 2010. For information about orders with delay and delivery errors from previous years we used excerpts from reports.

Qualitative secondary data included relevant information from the company's web site, such as structure and development of Spilka. We have also used the notes and preliminary results from Spilka's project on customer satisfaction. Table 3 below shows the data and information collected in the project, and how we have categorized it according to primary/secondary and qualitative/quantitative.

Table 3 **Overview of data collected in the project**

	Primary	Secondary
Qualitative	Causes for error General information	Literature Background information from web site Customer Satisfaction project
Quantitative	Lead time measuring	Log of errors Output from ERP system: -Customers - Sales - Part deliveries - Orders per customer - Orders per product Excerpt from report

The next two sections will give a more detailed description of interview and direct observation. These are explained further because they were the main data collection methods for primary data in the project.

3.2.1. Interview

Interview is a useful method for data collection. Interviews used in case studies are normally more guided conversations than structured queries. It is vital to ask questions in a manner that provides the needed information, but the questions should at the same time be reasonable and easy to answer for the interviewee. Different types of interviews are in-depth-, focused-, and survey (more structured) interviews (Yin, 2009).

In an *in-depth interview* the interviewer can ask about facts as well as the interviewee's opinion on a subject. The interviewee may also be encouraged to come up with propositions that may be basis for further exploration. From such an interview the interviewer may also get suggestions on other sources of information. Sometimes the interviewee will have the role of an informant rather than a respondent, which is important to have in a case study. An in-depth interview may take place over several meetings within a time period. *Focused* *interviews* have a shorter time span, like an hour. The interview may still contain open-ended questions and be more like a conversation, but it follows more strictly a predefined set of questions. *Survey interviews* follow more structured and survey-like questions. This type of interview is mainly used to collect quantitative data in a case study and are analysed as a regular survey (Yin, 2009).

Ellram (1996) separates the interview technique into unstructured, semi-structured and structured interviews. Unstructured interviews are conversational, while structured interviews may be in the form of a questionnaire.

Using interviews when collecting data can have several strengths and weaknesses. Interviews can be targeted and the interviewer can focus her questions according to what she wants to find out. Also interviews can be insightful and give the interviewer information and explanations from the interviewee (Yin, 2009).

Several weaknesses can also be mentioned about interviews as a data collection method. If the questions are not well formulated, the resulting information will not be as good as it could have been. Also the person being interviewed may provide inaccurate information due to poor recall. Another weakness is that the person being interviewed may be affected by the interviewer and answer what the interviewer wants to hear (Yin, 2009).

3.2.2. Direct observation

Direct observations may be useful to provide additional information about the topic. Direct observations can be both formal and casual data collection activities. Formal observations can be to observe meetings, factory work and so on. Observations are made throughout the field visit, for example in connection with an interview or other data collection methods. These kinds of observations are more casual. The reliability of the observations increases with the number of observers (Yin, 2009). We have to some extent used direct observations in this study. Spilka has allowed us to walk on our own in the office, production area and warehouse, which gave us the opportunity to make observations. Most have been casual observations in connection with data collection such as interviews.

Using direct observations has several strengths and weaknesses. The advantage with this data collection method is that the situation is studied in real time, hence the information is up-to-date. The observer will also cover the context of the case. On the other hand direct observations may be very time-consuming and there is a need for several observers to have broad coverage of the situation. Therefore it is also a costly method. The situation may also be affected by the fact that it is being observed, and it may therefore proceed differently (Yin, 2009).

4. Analysis

This chapter will present, analyse and discuss the results that have been found in the project. It is divided into three parts. The first section contains definition and description of the order process as well as analysis of the problems that might occur. The following section deals with value stream mapping, measuring and analysis of the process. Finally delivery performance is discussed, defined and measured.

4.1. The Order Process – Definition, Description and Analysis

In this section the elements of the order process will be described. First we will give a more detailed definition of the order process, followed by a description of the process steps. The last parts focus on errors in delivery and part deliveries.

4.1.1. Definition

In this thesis we define the order process as the sequence of activities associated with the filling of customer orders. An important step in the preparation phase of the value stream mapping is to clearly define the range and limits of the process. Therefore we have defined the starting and ending point of the order process below.

The order process starts when the order is received from the customer. There are three ways an order can be received: by e-mail, fax, or phone. We consider the process to have started when the e-mail appears in the inbox, the fax is received, or the phone rings.

The order process ends when the order is shipped, i.e. leaves the company. Additionally we include sending an invoice and receiving payment of the order. However this is just included as a confirmation from the customer that the order is received; we are not going to look into the payment process, and the lead time is only measured until the order is shipped.

Spilka produces and purchases to inventory, and in this thesis we consider this to be a separate process from the order process. The decisions made about when, what and how much to purchase and produce are not directly triggered by customer orders due to long lead time for the products Spilka buys.

We have limited the research to the order process for standard products, and disregarded special coloured products, since the process for these is different. For standard products Spilka produces to inventory, and not after orders, as mentioned above. Hinges with special colours are made after orders from the customer. According to Spilka the order process for hinges with special colours is good enough, and therefore we have not included these types in the thesis. Special colours are all colours except the standard gold, white and brown.

4.1.2. Description

Through the next pages we will try to elaborate on the order process at Spilka.

4.1.2.1. Entering the order

Receiving orders

There are several ways orders can be received at Spilka Industri. The order can either be handed in orally by telephone, or in written by fax or e-mail, which is printed out on paper. When the customer calls in her order the receiver at the office writes down the customer's order on a paper. After the order has been registered in Navision the note from the phone call will be filed according to customer name and order number. For orders handed in by fax or e-mail the document sent from the customer will be filed in the same way as the oral order.

Registration of Orders

All orders are registered in Navision at the office. Here the order is released so that the warehouse workers can start picking the order. All orders are automatically given its own order number by Navision, and this number is written on the order handed in by the customer. This makes it easier to track down the order if any problems occur.

For each order the person registering it at the office must perform inventory sourcing to check if the products requested in the order are available. The inventory level is displayed on the computer screen so that one quickly can determine if the order can be confirmed. If the products are not available she must call production to check if they will be able to produce more in time. Only after verifying the availability of products, the registration of the order can be completed.

Order confirmation

After the order is registered in Navision an order confirmation is sent to the customer. The order confirmation is automatically made in Navision based on the data from the order registration, and is sent to the customer by e-mail.

4.1.2.2. Pick and pack

Delivery Plan

The Warehouse office prints a delivery plan from Navision every Monday morning and also several times per week to include new orders. There is however no general rule for how often or when it should be printed. The delivery plan displays all orders within a certain date range, normally a week, but the range may vary. It shows the customers, the products and quantities, and also the shipping dates of the orders. The delivery plan also shows if a pick list for a specific order has been printed. The purpose of the delivery plan is to plan the picking of orders for a particular week. Since new orders arrive throughout the week it is important to print more than one list within a week, so that the warehouse always has the last edition of the list.

Pick list

By looking at the delivery plan the workers at the warehouse can see which orders they need to print pick lists for. The pick lists are printed from Navision in the warehouse office. After printing, the pick lists are stored in a shelf in the warehouse. Each order has its own pick list, which shows the products that are ordered, the ordered quantity and type of packaging. If the picker sees that there are several pick lists to the same customer, she can choose to pick and pack these orders together as one sending. Before the warehouse worker starts to pick the order she prints out customer labels that are later glued on to the different pallets. While packing the order the warehouse worker marks on the pick list when each product line is completed. If she uses pallets to pack the order she writes on the pick list the number of pallets that are used.

Confirmation of picking

After the picking is finished the warehouse worker confirms the picking in Navision. Here she updates the order and makes changes if she did not have all the products requested by the customer. If there is a lack of products the office is notified. Also she updates the number of pallets and pallet frames that are used on the order. After completing the confirmation of picking a sales shipment is printed from Navision. The sales shipment shows the contents and weight of the delivery. The sales shipment and the pick list are then delivered to the office.

4.1.2.3. International orders

The next two steps in the order process are special for international orders, i.e. orders that are sent out of the country. Otherwise the process is the same for both domestic and international orders.

Invoice

When it comes to international orders, the invoice is made at this stage of the process. The reason is that all shipments crossing the border must be sent with an invoice, if not they may experience problems with customs. This document shows customs how much the order is worth. The invoice that is sent with the order is not the original, but a copy. The original is sent to the customer by e-mail on the same day as the order is shipped.

Customs declaration

Spilka is authorized to fill out a customs declaration for the goods that are sent out of the country. The declaration is done through a program called Tvinn. After filling in information about the order they send it through the program to customs. This leads to shorter waiting time, since customs also answers through Tvinn. In this way the order is ready to be sent in a short period of time. When customs has responded Spilka receives a document called SAD, which shows who the sender and receiver are, the delivery terms, weight, part number and the total sum that is billed. It also shows how the duty credit is going to be paid. SAD is then forwarded to the transporter by e-mail. Spilka must store the customs declaration for at least ten years, since customs can choose to check their documents.

4.1.2.4. Booking of transport

Spilka mainly uses Consignor to book transport for their customers. In this program they can choose which transporter to use, and determine the cost of this transportation. Consignor is connected with Navision. By typing in the sales shipment number in Consignor they automatically get information about the customer and the destination of the order. The weight and number of packages in the order must be typed in manually. Another piece of information that must be entered into Consignor is whether Spilka or the customer pays for the transportation.

After all the information is entered into Consignor they can print out a document called "Today`s shipments". This document shows the transportation company what Spilka wants them to pick up this particular day. Bring is the only transportation company which prefers that they print and fax this document to them. For the other transportation companies it is enough to type in all the information into Consignor. When the transporter picks up the deliveries, she has to sign the "Today's shipments" document.

Some of Spilka's customers have their own transportation company that picks up their deliveries. For these customers the transporter arrives at Spilka on the day agreed on in the order confirmation. But if the order is finished earlier the office often calls to let them know the order is ready to be picked up.

After registering transportation three or four copies of the freight bill are printed out from either Consignor or Navision. For deliveries to customers with own transportation four copies are printed from Navision. Spilka keeps one of these copies in their files. For orders booked in Consignor the freight bill is printed from the same program, but here only in three copies. All three copies are sent with the order. The freight bill gives information about the sender, the receiver and the carrier, the number of pallets in the sending and the weight of the sending. The freight bill is brought from the office to the warehouse, and it is shipped together with the order.

When sending international orders by car Spilka makes an international freight bill called CMR. When international orders are sent with sea transportation Spilka sends all the information about the cargo to the transporter, who makes the waybill.

4.1.2.5. Shipping the order

The order should be shipped from the warehouse on the agreed date. Although there are two warehouse workers that can assist, the loading of trucks is done mainly by the drivers who are employed by transportation companies. The documents that follow the shipment are the sales shipment and the freight bill for domestic orders. The invoice is added to this for international orders.

4.1.2.6. Invoice

All invoices for domestic orders are made in Navision and are based on information from the pick list. As mentioned earlier, the invoice is sent with the order for international orders. For domestic orders the invoice is sent after the order has left the factory. After the order is sent to the customers all documents are placed in a folder in the office. Whenever the office personnel have time they do the invoicing for the orders that are placed in the folder. They try to invoice all finished orders before the weekend starts. All orders get their own invoice number. Each invoice shows what is delivered, and how much the customer must pay for the order. It also shows the unit price and the total amount for each product line delivered. Further the invoice shows if some products lines have not been delivered as promised.

It is most common to set a time limit for payment of 30 days from the date of invoice. However, there are different conditions, and sometimes the time limit for payment might be 45 days.

4.1.3. Errors in delivery

In this section the delivery errors will be presented and analysed. First the focus will be on the log of error, then the root causes of errors will be analysed before discussing costs of errors.

Errors in delivery can be defined as orders that are not delivered satisfactorily to the customer. We separate between errors in deliveries and part deliveries, which will be described later (in section 4.1.4.). In April 2010 Spilka started to file all discovered errors in delivery in a logbook. From previous years only information about the total number of errors is known, but the reasons for these errors were not filed. We have therefore decided to analyse only the delivery errors from 2010.

4.1.3.1. Log of errors

After going through Spilka's log of errors we were able to get an overview of the main types of errors that occurred during the previous year.

Spilka has divided the delivery errors from 2010 into six categories. The numbers in brackets indicate the number of times this type of error has occurred.

- *Wrong amount: (15)*

In this category the customer has received wrong number of items, for example 100 instead of 200. In some cases the product line has not been delivered at all, in other cases only part of it is delivered, and it has also happened that too much of an item is delivered. Orders that are delivered with the wrong amount of a product stand for the largest share of errors in 2010.

- *Wrong article number: (10)*

The customer has received a different product than ordered. In almost all of the cases there was only one digit that separated the ordered product and the received product. Products of the same type and size but of different colour have almost the same article number (gold coloured products start with 10 and white coloured products start with 11, but the rest of the article number is the same).

- *Labelling errors:* (6)

Pallets or cartons have been labelled as something else than what they contain. It may say on the label that the hinges are gold coloured, but they are actually white, or it may be labelled as right side hinges, but they are left side.

- *Other errors: (4)*

All errors in this category were production errors, i.e. products missing parts and not being complete when delivered.

- *Wrong customer: (1)*

This category includes product lines that are sent to a different customer than the one who had ordered them.

- *Wrong entering of order: (1)*

Errors that occur when orders are entered wrong into Navision at the office

(Spilka, 2010)

Figure 9 **Pareto chart of delivery errors**

Figure 9 is a Pareto chart illustrating the types of delivery errors at Spilka and how many times they have occurred during 2010. It is based on data from the log of errors. From the chart it can be seen that the three major error types (wrong number, wrong article number and labelling errors) together amount to approximately 85 % (the exact percentage is 84 %). In other words, eliminating these three types of error will improve the total number of errors by 85 %.

4.1.3.2. Root causes of delivery errors

After looking at the log of errors from 2010 we decided to carry out informal and focused interviews with workers at the warehouse. The interviews were performed with three of the warehouse employees who work on picking orders. We chose to use interviews as a data collection method because we needed help from the employees in the warehouse to come up with possible causes of the picking and delivery errors. The interviews were supposed to be informal and unstructured because we for the time being had limited information about reasons for errors so it was difficult to ask detailed questions. Instead we presented the different error types from the log of errors and asked for their opinions about possible causes of these errors. The category of *other errors* was not included in the interview since these were quality errors related to production. By asking an open-ended question we wanted to give the interviewees the opportunity to come up with different ideas that we might use as a basis for further investigation. We also wanted unstructured interviews to make it more like a discussion with the employees rather than very structured interviews. During the interview conversation we tried to use the 5 whys technique to go deeper into the causes they first mentioned. This means we asked the employees follow-up questions to the initial replies, although not necessarily by asking why as much as five times; this depended on the answers. Further we used the cause-and-effect-diagram tool to systematize and visualise the findings. The causes were categorized in the diagram using the 4M tool.

One type of error that occurred several times in the past year was orders with the *wrong number* of pieces delivered to the customer. The employees think this can come from problems with concentration and stress. Sometimes the pickers are disturbed by calls from the office while they are picking, because the office wants them to pick a more urgent order than the original order. The picker might then forget to mark a product line on the order she was originally picking, and then pick the product line again later. In this case the customer will receive more than what was ordered. This error has occurred in 2010. The workers at the warehouse say that it is important that product lines are not marked before the whole product line is picked, and this should not happen. If errors occur because the picker has marked the product line before it has been picked, there has been a failure in the work routines.

Further there has been a problem with other pickers borrowing items to their orders from other orders. The picker may have a more urgent order and items are missing. She then chooses to borrow items from another order that has already been picked and forgets to tell what she has borrowed. The picker with the original order does not know that her order is not complete and sends it as it is. The customer then gets the order with some missing items.

Another type of error that has occurred several times in 2010 is products delivered in the *wrong colour*. The problem is mainly between gold and white hinges. According to the workers the main reason must be concentration errors. Since the article numbers are quite similar it is easy to make mistakes when one is not concentrated. Sometimes the picker focuses on the size instead of the colour because she has picked gold hinges all day, and takes for granted that this order has gold hinges also.

In 2010 they also sent a product line to the *wrong customer*. The workers say that this type of mistake also can come from concentration failure. Some customers have long and difficult names, especially customers from Poland. When they have several orders to customers with quite similar names it can be easy to put the items on the wrong pallet. Especially when orders are waiting for missing items it can be easy to send it to the wrong customer. According to the warehouse workers they try not to place orders to customers with similar names close to each other, and therefore few products are sent to the wrong customer.

The problem with *wrong labels* has been addressed by Spilka. In the early autumn of 2010, Spilka changed its routines for labelling the pallets and some of the cartons. Up to this point the labelling was done by warehouse personnel when registering the product into inventory. They would then have a look at what was on the pallets or in the cartons before printing a label. Now this responsibility has been transferred to the machine operators, who attach a label right after manufacturing. When the warehouse personnel register the goods into stock, they may still have a look at the products, and therefore they may notice if something has the wrong label. The warehouse personnel say that errors still occur, but because of this extra check they are now more likely to be discovered and stopped before they leave the warehouse. By looking at the log of errors it can be seen that after changing the routines no labelling errors have occurred. This change of routines adds an extra step in the process which does not necessarily add value from a customer point of view. The best solution would be to have the products labelled correctly at once and not have an extra check. However the data indicate that the number of errors is reduced by doing it this way, so this step could be considered a non-value adding but a necessary step (type 1 muda). This is however not a part of the order process studied in this thesis.

Errors in order entry occurring in the order department are a small part of the log of errors. Often such errors are discovered before the order leaves the company. Customers often order the same products, and the warehouse workers know what type of products these are, so they can check with the office if something seems unusual to them. Very few errors in order entry therefore go through the system.

According to the employees at the warehouse errors often occur because of stress and concentration failure. After the temporary lay-off in 2010 they have had problems building up the inventory again. This will be explained further under section 4.1.4. about part deliveries. An effect of missing products is that the pickers must often wait for the products to be mounted. In some cases the trucks have arrived while they are waiting for the last items. This waiting causes stress for the workers at the warehouse, which can be a cause for errors.

A useful tool to identify and systematize root causes is the cause-and-effect diagram. The root causes for delivery errors, based on the interview with the warehouse workers, are presented in figure 10. To narrow down the root causes the 5 why method has been used.

The causes have been placed under three of the M's: Man, Materials and Method. The last M, Machine, is more related to production and could be associated with the other errors category, which we have not included. This is therefore left out from the diagram. The main causes have been divided into four levels. A first level cause is indicated by a blue arrow, a second level cause by an orange line, a third level cause by a green line and a fourth level cause by a red line.

Most of the causes have been discussed above, but a few of them may need to be explained further. Low inventory is a cause for waiting for missing items and is located two places under Method and once under Material. This may also be a cause for part deliveries, so it will be analysed further under this section (4.1.4.). Wrong labelling is not treated more thoroughly in the diagram since it has been addressed by Spilka, and it seems that the error no longer occurs. Some of the causes under Man, such as lack of concentration and forgetting to notify others about borrowing items, could be considered human errors and may be difficult to eliminate completely. A possible way of reducing such errors could be to establish a standard for notifying others when borrowing items from orders, and to make sure that everyone follows the same routine.

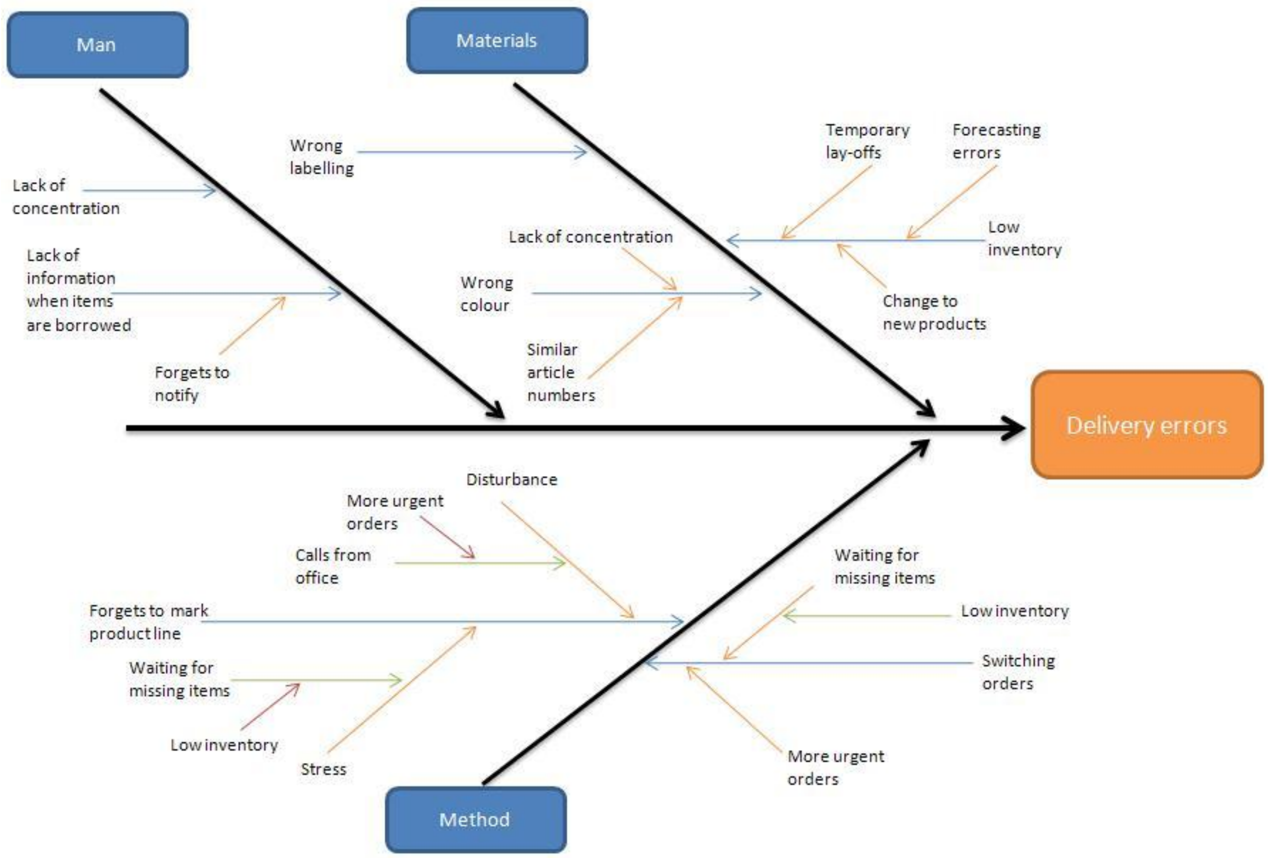

Figure 10 **Cause-and-effect diagram for root causes of errors**

4.1.3.3. Cost of error

Spilka will have several costs concerning the delivery of an order with an error. It is difficult to come up with an exact number for the cost, since there are several elements that impact the total cost. We will here try to go through the elements that can affect the cost of an error.

The cost when an order with error depends on both the type of product the error happened to, and who the customer is. When there is an error on an international order the cost will be larger than for a domestic order, due to higher transportation costs and more extra work regarding customs. Also it will take more time to correct an error for an international order, because of the distance from the factory. This can be crucial to the customers' satisfaction.

Spilka has stated that the customers' satisfaction is important to the company. The customers trust that Spilka will deliver the right product in the right condition to them as promised. When an error occurs to the order delivery it can harm the customers trust. The cost of dissatisfaction may not be seen after one error, but if several errors happen to the same customer the cost can be large for Spilka.

The transportation cost that Spilka must pay for an error will vary depending on the product and the location of the customer. When errors occur Spilka must pay both to transport the incorrect order back to their factory, and also to ship the correct product to the customer. To show what the transportation cost might be, an example will be presented:
The customer and product to be used in the example were chosen by the managers at Spilka. Uldal Vinduer og Dører AS is a customer located in Birkeland not far from Kristiansand in Norway. This customer was chosen because it is located more far away than most other domestic customers, but it is closer to the factory than the international customers. It was decided to look at the S5 hinge in pallets of 400 pieces, which is the standard size, and the most sold hinge. For this example the error is that Spilka has sent gold hinges, instead of white hinges. Bring is the main carrier that Spilka has an agreement with. For the calculation of the transportation cost we have used Bring as the transporter, and the cost was found by having the office check the price with them. The cost of sending a pallet with 400 S5 hinges from Ålesund to Birkeland with Bring is NOK 2412 each way, NOK 4824 in total. This means that Spilka will have an extra transportation cost of NOK 4824 to correct this type of error.

An element that we have not had the capability of measuring is the cost of all the corrections that must be done when receiving the incorrect order back at Spilka. This includes the reception of the products from the transportation and also changing the inventory level. Additionally there will be extra work associated with delivering the correct products to the customer, such as entering a new order, releasing new documents, picking and packing. Spilka will try to correct an error as fast as possible, and to do this they will pause the activity for another order, which can then increase the lead time for this order.

From the Pareto chart in figure 9 it can be seen that the errors with the largest share are products delivered in the wrong amount. This may not be the most costly error, since the transportation cost will probably be only half as much as for delivery of the wrong product. This is because Spilka does not have to take the products in return. There is no exact way to measure how large the cost of an error will be. But errors are costly to the company, both in terms of time and money, and should be eliminated or reduced.

4.1.4. Part deliveries

Part delivery means that a part of a customer's order is delivered later than the rest of the original order. In this section we will try to analyse the part deliveries at Spilka. The main focus will be on the part deliveries in 2010, but they will be compared to the previous years.

According to Spilka there are two main reasons why an order is delivered in parts. It is either because Spilka does not have the part available when the order needs to be sent, or because the customer needs a part of the order quickly, so that this is expedited. Unfortunately the data we have received do not indicate the reasons behind a part delivery. Data on part deliveries for each product were received from Spilka and it shows the number of part deliveries in the company each year encompassing both expedited orders and orders that could not be delivered completely. We can therefore not draw clear conclusions based on the data material only. However Spilka has expressed that part deliveries are a problem for them so we still used the data we had as an indication of the extent of the problem. To identify the root causes for part deliveries discussions with the Plant Manager were conducted.

Figure 11 below illustrates the development of part deliveries over the last four years. From the figure it can be seen that there has been an increase in part deliveries the last two years (2009-2010). In 2010 the number of part deliveries was as high as 146, which was the highest number of part deliveries over the years 2007-2010.

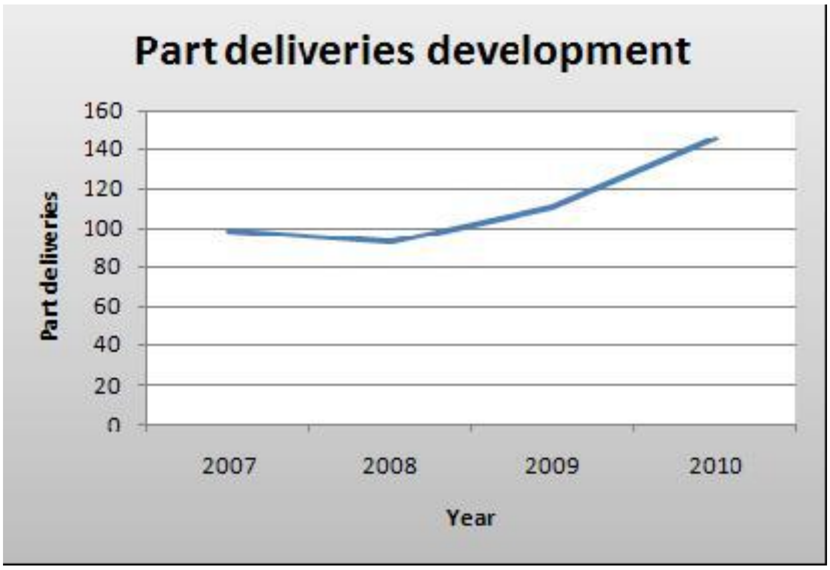

Figure 11 **The development of part deliveries over the last 4 years**

There are especially three products that stand for a large share of the part deliveries in the company. These three products are the head slide swing (13908) and safety catches for both the right and the left side (13915/13916). Together they account for 33 % of all part deliveries. The products are shown in table 4 below.

Table 4 **The products with the most part deliveries in 2010.**

Article number	Description	Part deliveries 2010	Share of part deliveries
13915	SAFETY CATCH RIGHT	43	13,44 %
13916	SAFETY CATCH LEFT	43	13,44 %
13908	HEAD SLIDE SWING	20	6,25 %

There are several reasons why these products have part deliveries. In 2010 there was larger demand for safety catches than Spilka had expected. Previously, safety catches were manufactured at Spilka's own production facility in Ålesund, but from 2010 they started to buy the product from a producer in China. There is a long delivery time for these products and therefore they had problems delivering when the demand rose. For the head slide swing (13908) one of the components is bought from another producer, so when there is a shortage of this component Spilka cannot manufacture the product. Therefore they can experience problems delivering the head slide swing. In 2010 they had larger demand for this product than expected, and therefore they could not deliver all products as promised.

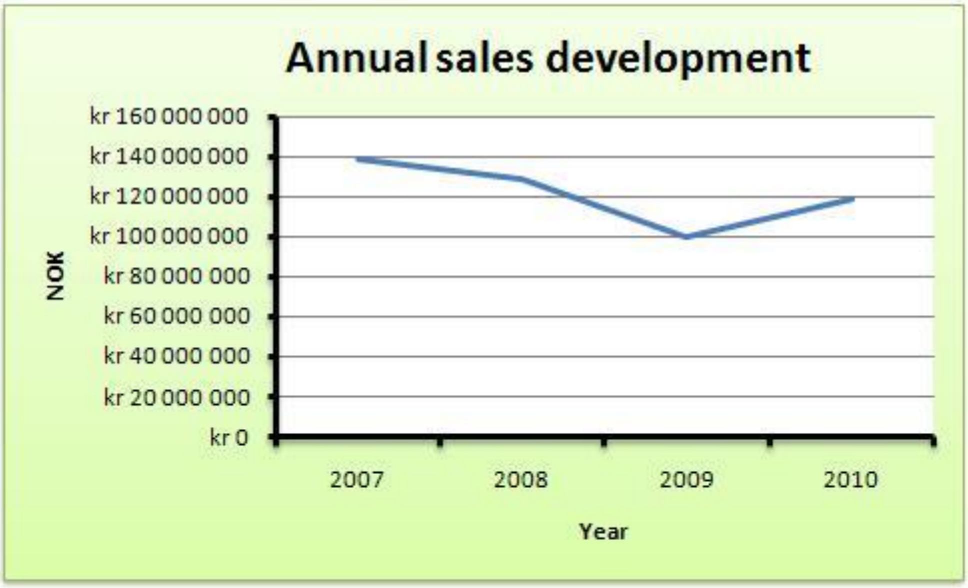

Figure 12 **Annual sales at Spilka over the last 4 years, based on internal data**

In figure 12 the annual sales development over the last four years is presented. By comparing figure 12 with figure 11 it can be seen that while the annual sales went down in 2009 the share of part deliveries went up. 2009 was an especially rough year for Spilka. There was a fall in the construction business which partly led to worse sales for the company. Because of the low sales numbers in January and February 2009, Spilka decided to lay off all their workers one day per week from March until the summer in 2009. Figure 13 presents the number of product lines for each month in the years 2008-2010, and here it can be seen that the spring months in 2009 were especially low compared to the other years. The dip in July is caused by the summer holiday, when Spilka closes for three weeks. After the summer in 2009 three of the key persons in warehouse were on sick leave. This meant that only one of the regular workers in the warehouse was still there. Also Spilka made some changes to their products because they faced new regulations. This meant that Spilka ran down their inventory level to make room for the new products. Because of the low inventory level Spilka experienced problems delivering everything as promised. As we can see there are several reasons for higher part deliveries in 2009 than the previous years.

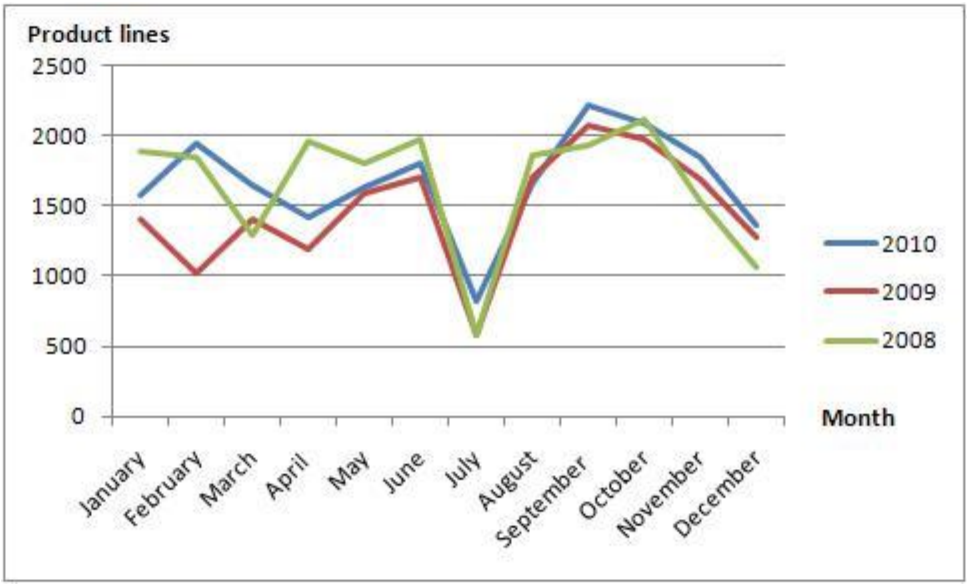

Figure 13 **Product lines delivered for each month (2008-2010), based on internal data**

In 2010 the annual sales started to increase slightly again, and the share of part deliveries still increased. After the rough year in 2009 Spilka used their customers' forecasts to plan 2010. Their customers were still worried that 2010 also could be a rough year, and presented fairly low forecasts. Spilka forecasted their budget about 20% lower than it actually turned out to be for this year. They also did their purchasing and staffing forecasting according to their customers' forecast. This might have affected the increase in part deliveries, since they did not always have enough capacity in terms of staffing and material to produce extra when the demand exceeded expectations.

One reason for the high number of part deliveries may be that Spilka tries to distribute the products equally when several customers have ordered the same products. This may give more part deliveries, but more customers will receive a part of their orders. Dissatisfied customers are of course something that Spilka wants to avoid, since this may be considered a cost for the company. Although this cost is difficult, if not impossible to estimate, they aim to reduce customer dissatisfaction through distributing the remaining products equally between customers whenever there is a shortage.

When Spilka is not capable of delivering all items that are ordered they try to send the remaining items with the next order to the customer. If it is urgent to get the products

Spilka must send the products as a single shipment to the customer. When this is the case, Spilka must pay for the delivery of the items. However, this does not happen often, so the main cost of having part deliveries is the extra time and work associated with packing and making new documents.

As mentioned in the beginning of this section, the large share of part deliveries does not necessarily come from shortages in Spilka's inventory, but it could also come from good service. The customer may want parts of the delivery earlier than the other, and then Spilka performs good service by delivering the urgent part of the order earlier.

4.2. Value Stream Mapping – Measuring and Analysing the Value Stream

In this section the method for measuring lead times will be described, followed by an analysis of the value stream and discussion of important results.

4.2.1. Measuring lead time

This section gives a description of how the measuring of lead times was done in the project. It will go through the challenges that occurred with the measuring, and how we managed to solve these problems. Finally it provides an overview of the limitations regarding this method of measuring lead times.

4.2.1.1. Planning and Execution

The measuring of lead times was limited to standard orders only, but we decided to measure orders from both domestic and international customers, since Spilka's sales are approximately equally distributed between Norwegian and international customers. We initially considered measuring only the orders with a number of product lines between 5 and 15 to avoid large variation between the orders. However, when we started the measuring we realized that not many orders were within this limit, so we decided to include all, regardless of the number of product lines. This resulted in a variation between 1 and 49 product lines. Still, many product lines of an order do not necessarily mean that the order takes longer time to pick. According to the employees there are other conditions that will have a larger impact on the picking time, for example the type of products, type of packaging and the quantity.

When planning how to perform the measuring of lead time we decided that the easiest way was to use the workers in the company. Since we are only two participants with limited time it would be difficult and very time-consuming to perform the measuring without help from the workers. Achieving the most accurate result would require us to follow each order using a stop watch and write down the duration of each activity. Instead, it was decided to make lists where the employees involved in the activities could help us by filling in date and time when they worked on the orders. In the beginning of the measuring we stayed in the office to help and answer questions about the lists if necessary.

Four different lists were made to cover the order process within the company. The lists were placed near the area where the activities were performed, to make it easier for the employees to note the date and time when they performed the specific tasks. To make the lists visible they were placed on desks. The working language at Spilka is Norwegian and therefore the original lists were made in Norwegian to simplify the process for the personnel performing the job. In appendix 8.1. a translated version of the lists used in the measuring process can be viewed. Six workers participated in the measuring, two in the office and four in the warehouse.

Two lists were made for the office. The first list covered the entering of new orders into the ERP system and was placed in the front office with the person responsible for entering orders. In this list dates and times for order entry was noted. She also wrote if she were interrupted in the enter order process, along with the reason for the interruption. The second list covered booking of transport for both domestic and international orders, but also making invoices and declaring goods with customs for international orders. This list was placed in the back office with the person responsible for these activities. She noted the date and time for the activities, as well as writing if there was some kind of interruption in the process, and the reason for the interruption.

Two different lists were placed in the warehouse, one in the warehouse office and one on the warehouse work desk. In the warehouse office the personnel noted the time when they had printed the pick list, registered the picking, delivered the papers to the office, and when orders had been picked up by the transporter. On the fourth list the pickers filled in the time the pick list was placed in the shelf, the time they started picking and the time the picking was finished. On the list they also noted if there was an interruption in the picking process, and if so, the duration and the cause of the interruption.

4.2.1.2. Challenges

Initially we planned to spend three days in February to start the measuring of the lead time. This means including the orders that were received during these three days in the measuring, and then following these particular orders through the whole order process. However, after finishing the first round of measuring we saw that it had been registered fewer incoming orders than expected. We then decided to spend three more days in March to start another measuring of lead time. A second round of measuring would contribute to making the results more representative for the company. The first measuring process was performed in week 6. According to the graph in figure 14, there seems to have been fewer product lines ordered that week than the adjoining weeks. The number of orders, however, does not directly relate to the number of product lines, since orders may comprise many or few product lines. We also had to eliminate some orders from our collection because they were orders for special coloured products. Nevertheless, the low number of product lines that week may be an indication of few incoming orders. For this reason we made another round of data collection approximately four weeks later. The second measuring process was started on two days in week 10 and one day in week 11. Also during these days of measuring quite few product lines were ordered.

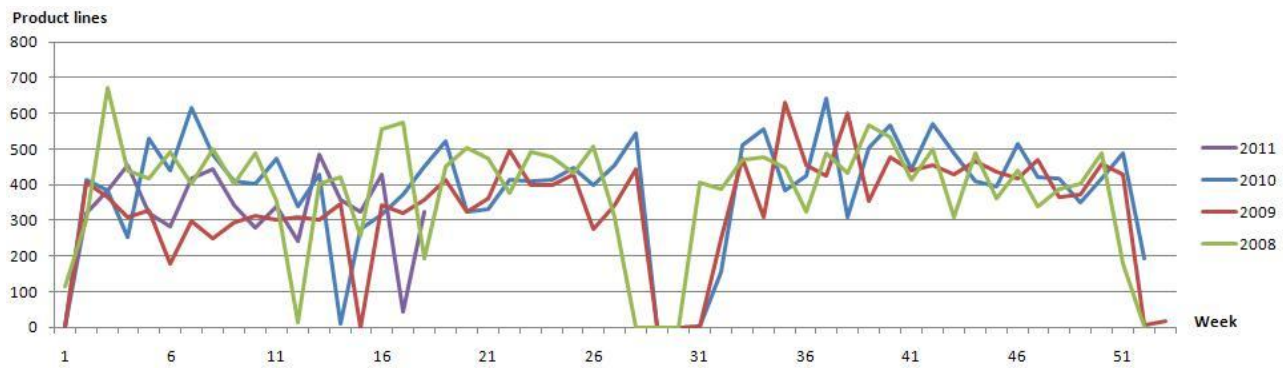

Figure 14 **Product lines delivered for each week (2008-week 18, 2011), based on internal data**

In the process we encountered a problem with different working times in the areas involved in the order process. At the time of our measuring the warehouse employees worked 30 minutes extra each day to work up extra vacation days, so they had 8.5 hour days including a 30 minute lunch break and a 10 minute coffee break. The total working time is then 470 minutes a day at the warehouse. It should be noted that this was only a temporary change in working hours. On the other hand the people in the office have working days from 7:30 a.m. to 3:30 p.m. or from 8:00 a.m. to 4:00 p.m. and only one break of 30 minutes. This amounts to 450 minutes working time a day.

This issue created a challenge as we wanted to measure the time an order spent in the company, across the different areas. We decided to handle it by making a clear distinction between the time the order was the responsibility of the office and the responsibility of the warehouse. Based on that we could separate between "office working hours" and "warehouse working hours". The exact working hours are shown in figure 15. The order is released from the first office activity when the registration is complete. The order is finished at the warehouse when the pick list and consignment note is delivered to the office. The last step of the process is finished when the order is shipped to the customer. For this we used the second office working hours, even though the activities include both the office and the warehouse. Lack of data in these activities for many of the orders resulted in a decision to look at the last part of the process, from finished booking transport until the order is shipped, as one activity.

Office working hours for order entry: 8:00 a.m. - 4:00 p.m.

Office working hours for booking transport: 7:30 a.m. - 3:30 p.m.

Warehouse working hours: 7:00 a.m. - 3:30 p.m.

Figure 15 **Working hours**

This decision implies that when an order is shipped at 7:05 a.m. (which is the case for a couple of orders), we do not count those 5 minutes since we assume that the working hours start at 7:30 a.m. for this activity. The consequence is that the accuracy of the data deteriorates, but 5 minutes is fairly little time compared to the whole lead time, so for simplicity we have decided to do it this way.

4.2.1.3. Limitations and possible errors

For some of the orders there have been dates and times that have been illogical from the rest of the measured activities. One example is an activity starting before a preceding activity has ended, so that there obviously has been a mistake. In some cases we decided not to include such orders, and in other cases we have exercised discretion about the points in time when transferring them to time spans.

For international orders the results from the measuring were not as detailed as we wished for when planning the lists. When planning the layout for the lists a short discussion was made with the office, but we should have included the order department more in planning the measuring process. As the lists were made it was decided to have both domestic and international orders on the same list to avoid confusion of having to deal with more than one sheet. In hindsight however it might have been better to use separate lists for the two types of orders in the office where transport is booked since the sequence of activities for international and domestic orders are different here. It would then probably have been easier to fill out the list if the steps were listed in the correct sequence.

In the time period the measuring took place only five orders from international customers were received. The results from these orders where fairly the same, and after discussions with the person responsible for the process with international orders we decided that we could use the information. For the activities that were the same for international and domestic orders we used all the orders to determine the process time for these activities. For the activities that were different, invoice and customs, we could only use the information from the international orders to measure the process times.

For international orders we have the date and time for when the invoice was printed in the office, but we do not have the exact time it would take to make the invoice. After further discussions with the person responsible for the process of making the invoices for international orders we agreed that it would take about five minutes to make an invoice. For domestic orders we did not measure the time it would take. According to the person responsible for making the invoices for domestic orders it takes only a few keystrokes on the computer to make an invoice. After observing several invoices being made we could conclude that it took approximately less than one minute to make an invoice.

From the lists we were not able to conclude the time that it takes from the order is shipped until the invoices were made. However, we knew the invoice dates because they are typed on the invoices. We therefore decided to assume that the invoices were made at 12 o'clock on the invoice date since this is at the middle of the working hours for the person responsible for this task. Using an average like this will lead to some inaccuracy, but we considered it to be an acceptable solution since most likely some invoices will be made before noon and some after. Orders that were sent after noon and invoiced the same day would then have a waiting time of 0. From this we could calculate an approximate time to use in the map.

When planning the measuring process we decided to only register the date and time the order is shipped from the warehouse, and not how long it takes to load the order onto the truck. The reason for this decision is that it is mainly the driver who does this task. When the truck arrives one of the warehouse workers will show the driver where the order is placed in the warehouse. Since this is not a time-consuming activity, we decided not to measure it. When measuring the lead time of an order it is more important to register the time it leaves the warehouse.
A possible source of errors in the measuring process can be that the workers performing the different activities used different watches. The results will therefore not be a hundred percent correct, but we do not think that the variations in time are too large.

Weekends are not included in the calculation of lead time. Since there is no activity in the factory in the weekend it is not reasonable to include the two days in the weekend in the lead time.

Another assumption we had to make was when an activity has started and ended at the same minute. We realized that the activity had happened, so we could not write a process time of zero, but at the same time it had taken less than a minute, so for these cases we used process time of 0.5 minutes.

4.2.2. Value Stream Mapping

The results of the measuring were used to make two current value stream maps of the order process, one for domestic orders (figure 16) and one for international orders (figure 17). These two maps were developed on the basis of a flow chart that was made after observations by one of the authors during the summer in 2010. During the process of making the final value stream map, several changes were made. The final map was then finished after discussions with managers and workers to correct what was missing and incorrect in the initial draft that was presented. In the value stream mapping process we wanted to find the lead time in the order process as well as the lead time and process times in the main activities defined in the map.

The icons used in the map are the same as presented in figure 6 in the chapter about value stream mapping in the theoretical framework. Some of the abbreviations and meanings may however need a short explanation:

Process time (P/T) is the actual time it takes to perform an activity. In the maps this time is presented in the data box as a range from the shortest time to the longest time that was registered during the measuring.

Lead time (L/T) is the total time it takes until the activity is completed including the time the order waits to be started on. The lead time is normally greater than the process time. In these maps the lead time is a sum of the averages of both the storage and waiting times and the process times including any interruptions.

The operators in the map indicate the number of people who know how to perform the activity, not necessarily the number of people who actually do it every day.

The information technology that is used is noted in a box in the bottom left corner of the process box.

The maps contain two *time lines*, one on the top and one in the bottom of the page. The number above or below a process box shows the average process time of this activity. Between process boxes there is a number showing the average waiting time between the activities. This time includes storage or waiting for someone to work on the order.

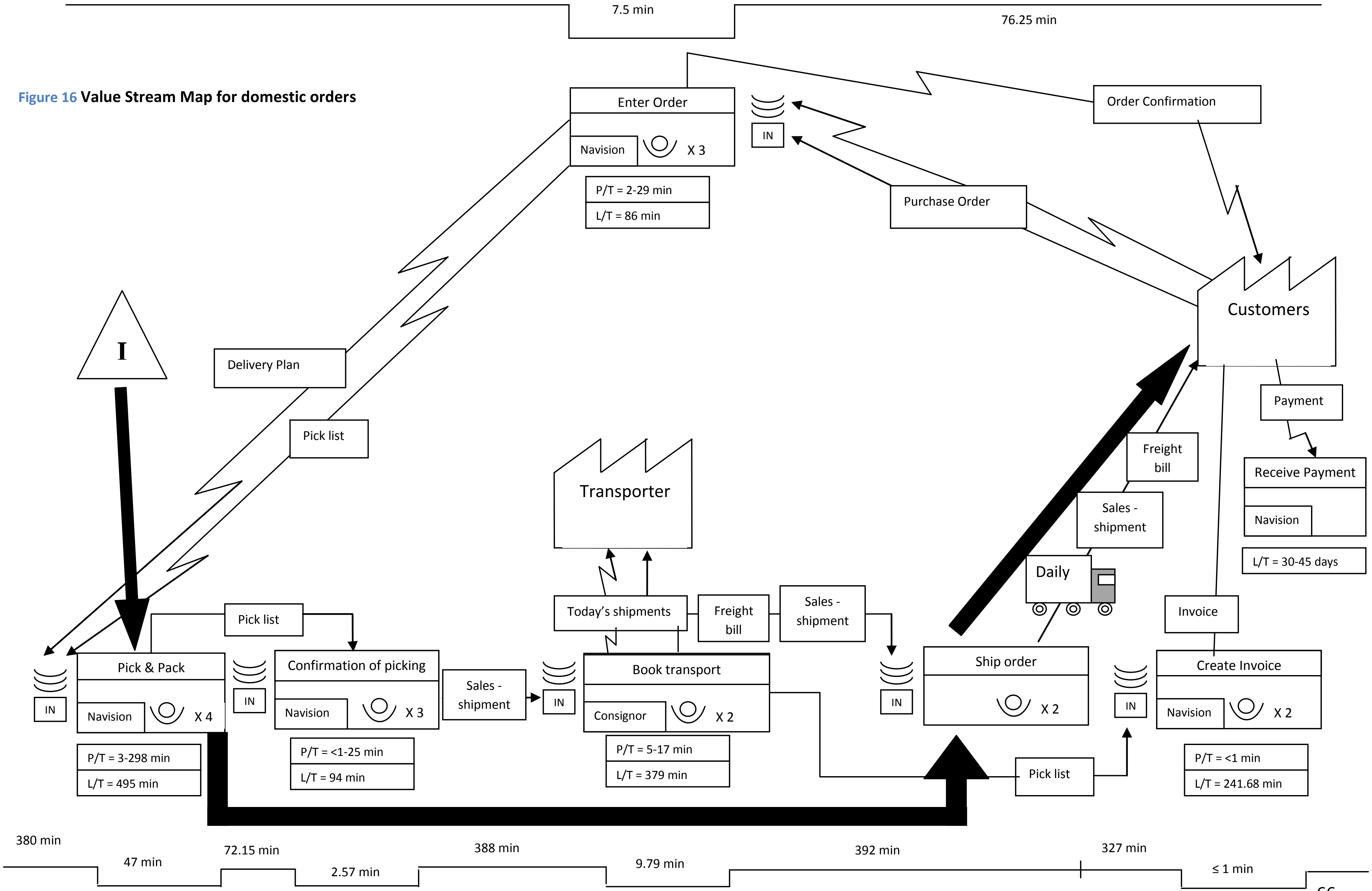

Figure 16 **Value Stream Map for domestic orders**

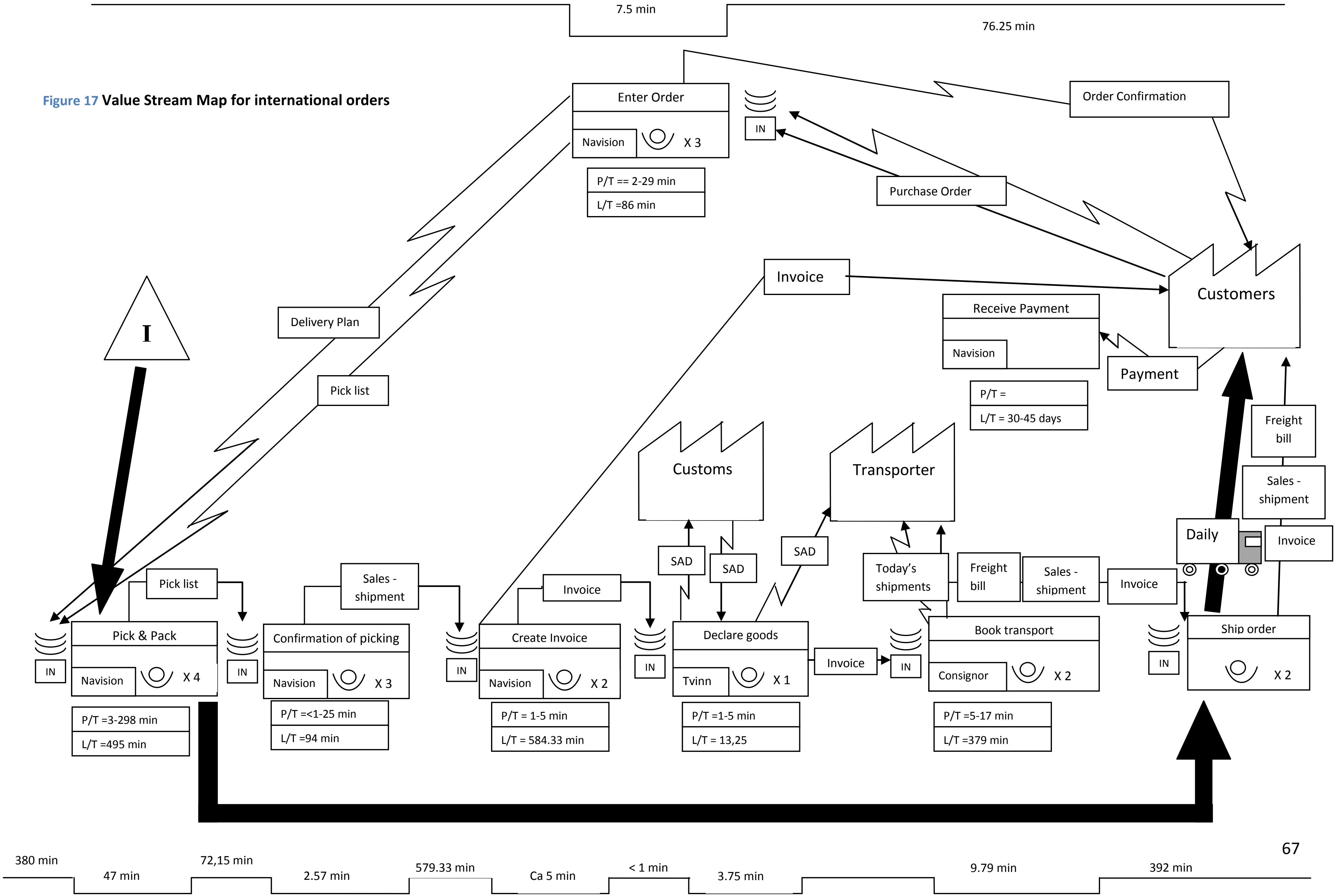

Figure 17 **Value Stream Map for international orders**

Altogether it was collected information from 24 orders, after some had to be left out from the result either due to lack of data or to obvious errors in the dates and times which we did not have the possibility to correct or check. Among those 24 not all are complete, but we were able to use part of the measuring even if the row for the order was not completely filled out. To get a better overview of the orders from the measuring we plotted all the information we had into an Excel file, which can be viewed in appendix 8.2. On the lists the points in time when certain events happened were registered, while these tables in the appendix show the duration between the points in time.

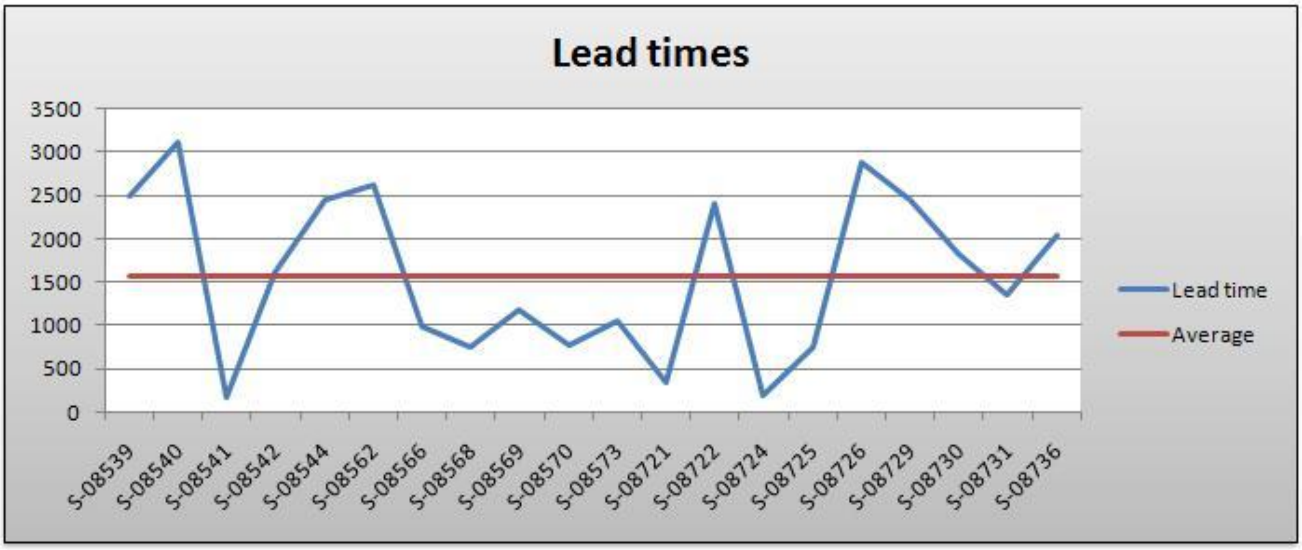

Figure 18 **Lead times**

In figure 18 the average lead time is presented together with the lead time for each order. After finishing the measuring we could see that there are high variations in the total lead time for the orders. There was also high variation in each of the activities that were measured. Total lead times range from 173 minutes to 3125 minutes with an average of 1572 minutes. In days this range equals 0.38 to 6.94 working days (weekends not included). Since Spilka has set a standard lead time of 14 days, it can be seen that all the measured lead times are within that limit. It is therefore not crucial to reduce the total lead time unless the limit of 14 days is reduced.

Because not all of the orders were completely filled out, the different activities have not had the same number of observations. The result is that while one time span has an average value based on 22 observations, another may be based on only 14. For some international activities there were as few as 3 observations, so these results were presented for the responsible person, who confirmed that they seemed reasonable and representative. When the averages of the time spans are summed, one would normally get the same result as the lead times that are found by calculating the time between the start and the end of the process. Here, on the other hand, these values are different because for some orders only parts have been used. Figure 18 shows the lead times calculated from start time to end time (average 1572 minutes), while figure 19 and figure 20 use the sum of average time spans (1447 minutes for domestic orders and 1657 minutes for international orders).

Figure 19 Lead time divided into activities for domestic orders

Figure 19 illustrates the lead time for domestic orders and how it is divided it into activities. The green colour indicates activities where work is done on the order: entering the order into Navision, picking, and booking the transport. We could also include shipping the order as a green activity, but this activity was not measured in the process. The green activities are the only value adding activities in the process, see figure 21. It is necessary to define which activities that are value adding and which that are non-value adding. Typically value adding activities are those that transform raw materials into finished products. However since the unit of analysis is order handling and not manufacturing of a physical product, the value adding activities should be those that transform a purchase request from a customer to a collection of items that is finished packed and sent to the customer. In this process we therefore consider these three activities marked in green to be value adding.

The yellow colour indicates storage of the documents to be handled, while the orange colour is waiting time for someone to start the next activity. According to the seven wastes, waiting time is not adding value to the process and should be eliminated. When the order is stored it remains unchanged and so this is also non-value adding (type 2 muda). The purple activity is the confirmation of picking, and this is an activity that might not create value for the customer. On one side, it is doubtful that the customer would be willing to pay for this process step. On the other side this confirmation is also an extra check where errors may be detected. If the pick list has shown that not all items were available, but still the picker has been able to pick all and complete the order, then this must be updated into the system. Since Spilka needs to register what has been picked, the confirmation of picking may be considered a non-value adding but required activity (type 1 muda).

The blue colour indicates an interruption to a value adding process step. On average there are almost no interruptions to entering of orders and booking transport, but the picking process is interrupted longer and more often because they have to wait for products to become available for picking. The interruption is considered non-value adding (type 2 muda). An interruption in the enter order step could however in some cases be value adding if the cause of the interruption is to call the customer to get necessary information regarding the order. The white colour is the time from the order is shipped until the invoice is made. Since this happens after shipping the order it is not included in the total lead time.

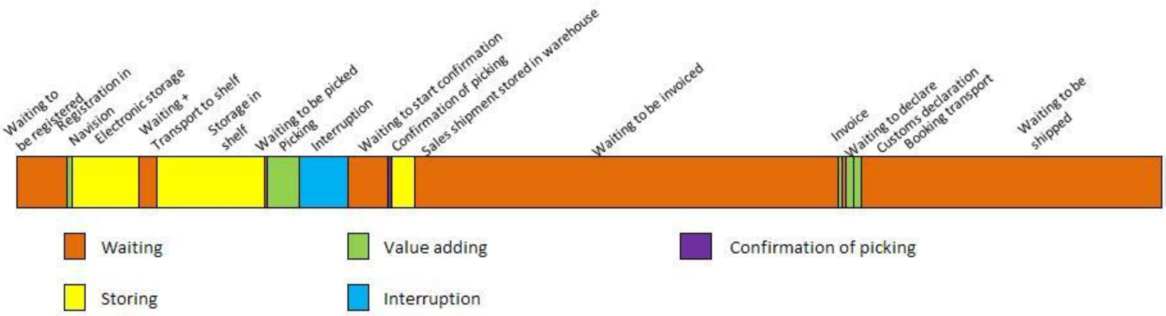

Figure 20 **Lead time divided into activities for international orders**

In figure 20 the lead time is divided into activities for international orders. Most of the activities are the same as for domestic orders, but two extra value adding activities are included: making the invoice and the customs declaration. The total lead time for international orders is longer than for domestic orders, but here the invoice is made within the total lead time and not after the order is shipped as it is for domestic orders.

If the activities should be divided into only three colours, red representing non-value adding activities (type 2 muda), purple representing non-value adding but necessary activities (type 1 muda) and green representing value adding activities, it would look like figure 21.

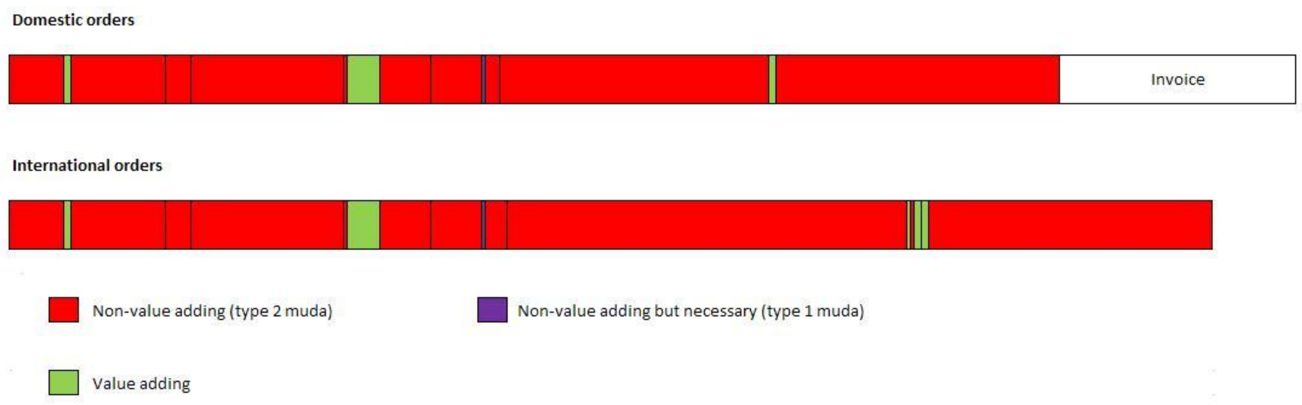

Figure 21 **Lead time divided into value adding and non-value adding activities**

Most of the non-value adding time in the order process is waiting time and storage time, and not activities that require the order to be handled by people. By reducing the waiting and storing time Spilka will not get more worker capacity, but reduced lead time to the customer.

From figure 21 and figure 22 it can be seen that most of the time is non-value adding and only a small part of the lead time in the order process can be seen as value adding. This can also be shown by the process cycle efficiency, which is calculated by dividing the value adding time with the total lead time.

For domestic orders the process cycle efficiency is:

$$\frac{Value\ add}{Total} = \frac{64.27\ minutes}{1447.07\ minutes} = \mathbf{4.44}\ \%$$

For international orders the process cycle efficiency is:

$$\frac{Value\ add}{Total} = \frac{78.79\ minutes}{1656.64\ minutes} = \mathbf{4.76}\ \%$$

The process cycle efficiency shows that the share of value adding time is 4.44% of the total lead time for domestic orders and 4.76% for international orders. This is not abnormal for a process. George (2003) says that typical process cycle efficiencies in services are about 5 %, and that the work spends most of the time waiting. A Lean process should however have a process cycle efficiency of 20 % or more. If we had measured the time it takes to ship the order the process cycle efficiency would increase slightly, but not as enough to achieve a PCE of 20%. The proportions of value adding, non-value adding but necessary and non-value adding time for the order process are illustrated in figure 22.

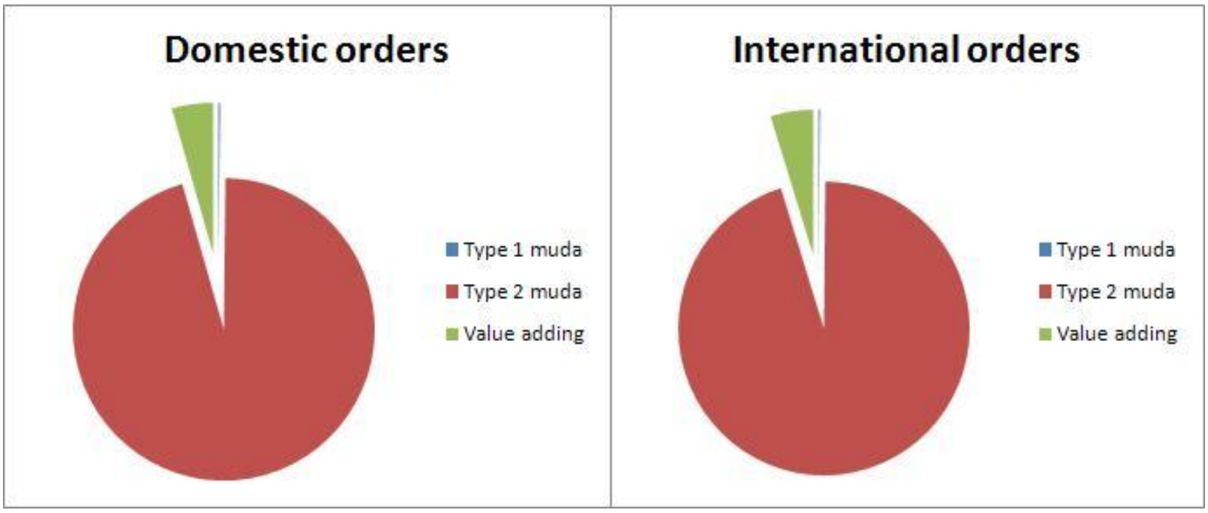

Figure 22 **Value adding time**

4.2.3. Results of importance from the measuring

- The picking process was on average interrupted for 68 minutes per order (0-515 minutes), and the main cause for the interruption was waiting for products to become available for picking. There are 4 orders that have been interrupted and 13 orders that have not been interrupted.

- On average it takes about 72 minutes from the picking is finished until the confirmation is started (0-573 minutes). It takes on average 20 minutes (2-172 minutes) after the confirmation is finished before the documents are delivered to the office.

- It takes on average 368 minutes (0-1835 minutes) from the sales shipment arrives in the office until she starts to book transport.

- Invoicing for domestic orders is done in batches and normally twice a week on Wednesdays and Fridays.

- The average order-to-cash lead time (time from order arrives until payment is received) is approximately 34 days. This is the sum of average lead time (3.5 days), average time before the order is invoiced after it is shipped (0.73 days) and time to collect cash (30 days).

- Average lead time was 1572 minutes (approximately 3.5 working days), and the maximal lead time was 3125 minutes (approximately 7 working days).

- In 2010 Spilka received 2572 orders. One year normally consists of 230 working days (Skatteetaten, 2007). This means that on average Spilka receives a little more than 11 orders per day. One day consists of 450 minutes real working time. Takt time will then be 450 minutes/11 orders = approximately 40 minutes/order. This means that on average one order should be entered every 40 minutes.

- The average process time of entering an order is 7.5 minutes. The average process time for picking an order is 47 minutes.

4.2.4. Discussion of the results found in the measuring

From the results it seems that approximately one fourth of the orders are interrupted when picked. In the interviews with employees regarding causes of errors, switching between orders was mentioned as a possible cause. This may be an indication to try to avoid interruptions. In order to reduce switching between orders, one should ideally wait to start the picking process until all goods are available to be picked.

According to the results for many of the orders, there is a delay from the picking is finished until confirmation is started. One of the Lean principles is flow, and to ensure good flow queues and delays should be reduced to a minimum. A delay between picking and confirmation should therefore be avoided. After confirmation of picking is done the sales shipment document which is printed at the end of this step has to be transported to the office. In the current process this transportation is necessary because the office needs the document to book transport or make the invoice, but it does not add value to the customer and may be considered type 1 muda.

In the current situation the sales shipment is printed in the warehouse office after finishing the confirmation and is then transported to the office. Results from the measuring showed that it takes some time before the document is delivered to the office. In Lean unnecessary transport is defined as one of the seven wastes, which should be eliminated. The conveyance of documents to the office may be considered unnecessary transport if there is another possibility to achieve the same result. By avoiding this transport the warehouse workers will also have more available time to spend on other activities.

The sales shipment waits for some time in the office before transport is booked. This may indicate that the person booking transport does not perform this task too early. On the other hand the waiting time could indicate that the order is picked earlier than required. However a reason for this may be that Spilka faces variable staffing and demand.

The order department believes that the best and most effective way to make the invoices is to make them in batches for domestic orders. This way of performing the invoicing can be discussed. According to Lean thinking, companies should try to reduce batch sizes and come closer to a one-piece-flow. Applying this to invoicing would mean to create the invoices at the same time as other office activities are done to the order, to reduce the office lead time and create a one-piece-flow in the office. By doing it this way one would complete the work associated with that order and avoid having to go back to the order at a later point in time. The benefits would be reduction of time and effort needed to retrieve necessary information regarding the particular order. It would also lead to a reduction of order-to-cash lead time since the invoice would be sent earlier and consequently the payment is received earlier.

Both the average and the maximal lead time from the results were considerably lower than the standard lead time of 14 days, which may indicate that the standard lead time could be reduced. A long lead time may act as a buffer and contribute to hiding problems, and therefore reducing consequences if errors occur. Having a relentless search for errors involves removing buffers. Reducing the lead time often reveals problems that one might not be aware of, so that there will be a continuous focus on preventing errors. However we have to keep in mind that, according to the employees at Spilka, this has been a period with low activity and that lead times therefore may be longer in peak seasons.

The takt time of 40 minutes per order is longer than the time it takes to enter the order so it is sufficient to have one person performing this task. On average it takes 47 minutes to pick one order, but here there are four people who can pick if it is necessary. They also have other tasks to perform so they do not spend all their time picking. Two of the warehouse workers are responsible for packing hinges into cartons. The warehouse is also responsible for registering the finished products into inventory, and for placing incoming material from suppliers into inventory. By comparing the average process time for picking of 47 minutes to the takt time of 40 minutes, it would seem reasonable that no more than two full-time equivalents are needed for picking orders. However both the process time and the takt time may vary due to high variations in picking time and variable demand.

The takt time should set the pace for the activities in the company. This implies that all activities should aim at processing an order every 40 minutes. If this is implemented it could be possible to get the order through the process in shorter time than it is today, and Spilka would then be able to reduce the standard lead time of 14 days. This requires that all products are available for picking when needed, which may be hard to accomplish without more accurate forecasts and production plans. We are not going deeper into this area in the project, but the company could consider studying this further.

4.3. Delivery performance

The literature includes many definitions concerning delivery performance, which also is called service level, delivery service or similar terms. Willoch (2005) mentions service level as a useful quality metric. Service level is the product of two factors; the completeness of the delivery, i.e. the share of ordered items that is received by the customer, and the precision of the delivery, i.e. whether the time of delivery is in accordance with the agreed upon time. Lutz, Löedding and Wiendahl (2003) define service level as the ratio between the number of orders satisfactorily delivered to the customer and total number of customer orders. Persson and Virum (2006) describe delivery service as the customer's view on the quality of the logistics activities. The term encompasses several elements, such as service level (probability for having a product in stock when needed), lead time, delivery reliability (delivery at the right time), delivery security (delivering the correct amount of the correct product in good condition), flexibility, information between supplier and customer, and ability to adapt to special requests from customers. There is therefore not a single definition of how this can be interpreted and measured.

The basis of how to measure the delivery performance was made together with the Plant Manager and the Managing Director at Spilka. It was decided to create an Excel-tool in order to facilitate continuous measuring of delivery performance. We looked to the literature to see how it had been done in other situations and to get background material for how we could develop a definition that suited Spilka's needs and wishes.

Spilka has not previously had any clear definition of delivery performance, nor have they defined any quantifiable target as to how they wish to perform in this area. Nevertheless, from meetings with and feedback from customers they have gained an understanding of the most important factors for the customers when it comes to deliveries. Through discussions with the managers regarding this issue, we may sum up the feedback from customers and Spilka's opinions in three elements under the concept of delivery performance. Below each element there is a suggestion on how this can be measured:

- **Delivery correctness**: whether the order is delivered without errors, i.e. correct product in correct amount with the correct label. In this context we disregard product quality errors as it is beyond the scope of the project.

$$\boldsymbol{Measure}: \quad \mathbf{1} - \frac{\boldsymbol{number\ of\ orders\ with\ errors}}{\boldsymbol{total\ number\ of\ orders}}$$

- **Delivery completeness**: whether the order is delivered completely, i.e. no part deliveries.

$$\boldsymbol{Measure}: \quad \mathbf{1} - \frac{\boldsymbol{number\ of\ part\ deliveries}}{\boldsymbol{total\ number\ of\ orders}}$$

- **Delivery precision**: whether the order arrives at the customer at the agreed time.

$$\boldsymbol{Measure}: \quad \mathbf{1} - \frac{\boldsymbol{number\ of\ orders\ with\ delay}}{\boldsymbol{total\ number\ of\ orders}}$$

All of the elements have to be measurable using already existing data material. The delivery correctness can be measured by dividing the number of errors by the total number of orders and subtracting the answer from 1. The number of errors is found in the log of errors, and the total number of orders is registered in Navision. Measuring the delivery completeness can be done by dividing the number of part deliveries by the total number of orders and subtracting the answer from 1. The number of part deliveries is also found in Navision. The third element, delivery precision, is measured by dividing the number of orders with delay by the total number of orders. Information about orders with delay is found in an Access report with data from Navision which contains an overview of these numbers for each quarter since 2007 (Spilka, 2011e).

After consulting with the plant manager at Spilka it was decided that each of the elements should be weighted equally with ⅓ on each. This can easily be changed at a later time if the priorities change. The formula for calculating the delivery performance is then:

$$(\boldsymbol{Weight1} \times \boldsymbol{Delivery\ Correctness}) + (\boldsymbol{Weight2} \times \boldsymbol{Delivery\ Completeness}) + (\boldsymbol{Weight3} \times \boldsymbol{Delivery\ Precision})$$

Calculating this number should be done at regular intervals to measure if the delivery performance improves or deteriorates. The easiest would be to use annual numbers since much of the data needed are given for each year.

To calculate the delivery performance within the company a spreadsheet in Excel was made. The aim was to make the activity of calculating the delivery performance as easy as possible for the company. To make it user friendly for Spilka it was decided to make two versions of the spreadsheet, one in English and one in Norwegian. Screenshots of the English version can be viewed in appendix 8.3. The data used in this Excel spreadsheet is taken from an internal meeting report about the quality system (Spilka. 2011f).

In 2010 Spilka had 2572 orders. 33 errors in delivery were registered, which gives a delivery correctness of 98.7 %. There were 146 part deliveries, and this gives a delivery completeness of 94.3 %. The number of orders with delay was 81, which resulted in a delivery precision of 96.9 %. The result after weighting and summing up these three elements is a delivery performance of 96.63 %. It is hard to determine whether this is a good result. It was lower than the delivery performance of the two previous years (with 97.2 % and 97.9 %, respectively), but slightly higher than 2007, which had 96.5 % (see appendix 8.3.2. for calculations).

As stated in the last research question, one of the objectives of this thesis was to improve the business process at Spilka so that waste is reduced and delivery performance is improved. This is a twofold objective; however both may be results of process improvements. Reduction of waste involves reducing or eliminating activities that have no value from a customer's point of view. For each unnecessary step of the process that is removed, the total lead time of the process will be reduced. One of the elements defined under delivery performance is delivery precision. A shorter lead time will hopefully result in fewer orders with delay, higher delivery precision and consequently higher delivery performance. An example of this may be to reduce waiting time, which in this case is the time the order is waiting to be handled. Waiting is one of the seven wastes described earlier, and reducing this will reduce the lead time.

Another waste that might be connected to delivery performance is defects. A defect is a product that does not meet customer specifications. In the context of this thesis a defect can be an order that does not meet customer expectations in terms of correct amount and correct items at the expected time. An order is a defect if there are errors, delays or part deliveries caused by lack of available items. Reducing errors and part deliveries, i.e. defects, will therefore affect the delivery performance in a positive way.

However there may not always be a correlation between increased delivery performance and reduction of waste. Eliminating non-value adding activities may not necessarily have an effect on the number of delayed orders or other aspects of the delivery performance. The customers may not be affected; however the reduction of waste will still benefit the company through freed-up time that workers can spend on value adding activities.

5. Conclusion and recommendations

This chapter presents the conclusion, followed by recommendations to the company based on the findings in the analysis.

5.1. Conclusion

The objective of this paper was to improve business processes in Spilka, in particular the order process. This includes identifying problems and their root causes to determine where focus should be placed. Further it was aimed at establishing a definition of delivery performance and metrics for how this could be measured. With Lean and Six Sigma as a framework the project focused on finding ways to improve the business process so that waste could be reduced and delivery performance increased.

Through this paper it has been shown that the main problems are errors in delivery, and part deliveries. Further investigations revealed causes for the problems, and the use of Lean tools enabled the authors to explore and categorize the errors. By using tools to visualise this, Spilka can become more aware of the causes of errors and with that make strategies on how to prevent and eliminate them.

Through using the Lean tool of value stream mapping, the order process has been visualised using standard mapping icons. Further, a method of using lists and help from employees has been used to measure process times, waiting times and total lead times. The results show that there are possibilities for reducing waste in the order process at Spilka. A large share of the time an order spends in the company is non-value adding, and most of this is waiting time.

Based on the problems in the order process there was established a definition of delivery performance and a tool was developed so that Spilka can measure this. Continuous improvements require relevant metrics in order to measure the extent of the improvement. By identifying possibilities for improvements and reducing waste, delivery performance could also be improved.

The analysis has led to the formulation of recommendations that Spilka may implement in order to hopefully reduce waste and improve delivery performance. In this thesis the analysis has focused on the order process but the method is not specific for this type of process and can be applied to other business processes as well.

5.2. Recommendations

Visualise current performance

At certain time intervals, say once a week or once a month, Spilka could post an overview showing the performance for the previous time period. This overview may show the errors that have occurred in order to increase the awareness about errors and to prevent them from happening again. Such an overview could also include other relevant metrics, like the number of orders that have been received, delayed orders, part deliveries etc. It is important that the overview is posted a place where it is easily visible to the people involved in the process. This is a form of visual management in order to keep everyone informed about the process performance, whether it has been good or not so good, and to show if there has been improvement from previous time periods.

Delivery performance

In the project a tool in Excel was developed to help measure the delivery performance at Spilka. Spilka should develop goals on how the delivery performance should be. What is the desired level for each element, and what is the lowest acceptable level of performance. By dividing the delivery performance into three elements, it is easier for Spilka to see which parts are not doing so well and should be improved. Further it is recommended that Spilka performs continuous measuring so that they are aware of the level of delivery performance. The easiest way is to use annual numbers to measure at the end of each year, but the Excel tool is developed to help Spilka calculate delivery performance at shorter intervals if needed.

Establish a standard for the customs declaration

The current situation is that only one person makes the customs declarations on international orders. In the long term it may be necessary to train others in this activity too, so that more people are able to perform this task. Declaring goods can be a complicated process, so it might be beneficial to establish a standard for how this work should be done.

Wait to pick product lines until all items are available

Today parts of the product lines are picked while waiting for the items that are missing. An improvement that can be recommended is that the picker does not pick the available items on the product line until all items are available, or that she is certain that the whole quantity of the product cannot be sent. A possible cause for errors is that orders cannot be completed due to lack of products and that the pickers have to switch between orders. By waiting to start picking a product line until all items in that line are available, the product line will not be only partly picked and the risk of errors diminishes. The optimal situation would be to wait to pick the whole order until all items of the order are available, but this would be hard to implement in Spilka since they have variable staffing and demand. It would also require them to have a higher inventory level.

Confirmation of picking

According to the results from the measuring process the confirmation of picking is not started directly after the picking is ended, but there is often some waiting between these two activities. It could be better to do the confirmation of picking immediately after the picking to reduce the time the order is waiting. Additionally, since the inventory level registered in the ERP system is updated through this confirmation, the sooner it is done, the more up-to-date the inventory level in Navision is.

It might also be worth looking into ways to eliminate this activity since it is non-value adding, although it for the time being is necessary in the process. Spilka could aim at implementing a solution with real time registration of picking, so that the confirmation is done simultaneously as the picker is working. This could increase the accuracy of registration as well as reduce the time spent. Solutions that Spilka is considering are the use of bar codes, where the items are scanned, or pick by voice, where information about the items to be picked is given through a headset.

Print the sales shipment at the office

To avoid unnecessary transport it could be worth looking into the possibility to print the sales shipment at the office instead of at the warehouse office. Even if it is a part of the confirmation of picking activity, the sales shipment is needed at the office to book the transport. Since the warehouse does the picking and therefore knows the completeness of the orders, the confirmation of picking should still be performed in the warehouse office. The warehouse could then notify the office when the confirmation is complete and the sales shipment is ready to be printed. The results could be reduced storage time of the sales shipment in the warehouse office and reduced transport.

Creating invoices after booking transportation

A recommendation can be to create invoices directly after booking transportation for domestic orders, in order to improve the flow of office activities. Currently invoices are made in batches every Wednesday and Friday, and orders can be waiting to be handled up to two days before invoiced. Since the invoice is made by a couple of key strokes it would be less time-consuming to create the invoice while work is still done with the order on the computer. This will also decrease the office lead time and order-to-cash lead time.

Reducing standard lead time

Spilka could consider reducing the standard lead time, which today is 14 days. The results of the measuring have shown that the lead times are generally much lower than the standard, and an improved process should be able to handle an order in shorter time. By reducing lead time, problems in the process can easier be found, and Spilka can improve the quality of their deliveries.

Continuous improvement

An important aspect of process improvement is the continuous search for improvement possibilities. It is important to include all employees in the search for improvements, and the DMAIC methodology provides steps to guide them in this work. Continuous improvement implies that at the same time as a worker is performing an activity, she should also be searching for better ways to do it. It is therefore recommended that Spilka includes their employees in the search for errors and establishes routines to reduce them.

6. Limitations and further research

This chapter presents some limitations of our research, followed by suggestions for further research.

6.1. Limitations

There are certain limitations in this paper. Limitations regarding the method of measuring lead time using lists are also discussed in section 4.2.1.3. When measuring lead time the work was not done by the authors, but by the workers in the company while performing their regular tasks. This might have affected the accuracy of the results. For some parts of the process the information registered about the orders was incomplete, which resulted in a decision to combine several activities in the analysis. We also exercised discretion in the process of transferring data from the lists to time spans in the Excel sheet, and tried to obtain a result that is as correct as possible.

Process time of making the invoice was estimated by the responsible person after the measuring. Also both rounds of measuring took place in a time period with a low demand from customers, which resulted in a lower number of orders than expected when planning the process. With a higher number of orders measured the results could have been more accurate and representative.

It can be discussed if the results from international orders can be seen as representative for all international orders. Since few orders to international customers were registered during the measuring it was decided to use parts of the domestic orders for many of the measured activities that are similar for both. For the activities that are special for international orders, such as invoice and customs, there are few observations. Some of the results for international orders are therefore approximate numbers.

Data used to analyse part deliveries were based on orders with more than one invoice. It was therefore not possible to determine the exact number of part deliveries caused by Spilka not being able to deliver, since the data also included parts of orders that were expedited.

6.2. Further research

This section contains an overview of further research that can be carried out related to this thesis.

The order process is closely connected to the procurement of products to inventory. When the picking process has to wait for missing items, it is because they are not available in stock. Further research could look into reasons why the products are not in inventory when needed. This could involve looking into forecasts, purchasing and co-operations with suppliers as well as production planning.

Warehouse layout is another area for further research, which is related to the picking activity. Minimizing time spent and the distance the pickers have to walk to get the products on the pick list would contribute to more efficiency in picking and a leaner process. By placing the products in the warehouse according to predefined criteria like frequency of picking, value, size etc, the warehouse layout could be optimized.

Further research could also be done on the routines for picking. By improving routines and making a standard for how it should be performed human errors might be reduced. Also a standardization of routines can make it easier to cross-train workers to perform other activities than normal when needed.

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8. Appendices

8.1. Lists of measuring

8.1.1. Order Entry List

				Fill out if interrupted during the registration	
Order number	**Received in inbox**	**Start registration in Navision**	**End registration in Navision**	**Why was the registration interrupted?**	**How long was the registration interrupted?**
0123456	19.01 – 14.52	20.01 – 10.00	20.01 – 10.15	Phone call	5 minutes

NB: All orders must be filled out with both date and time.

8.1.2. Booking of Transport List

			Fill out if interrupted during the registration					Special for international orders	
Order number	**Start registration in Consignor**	**End registration in Consignor (+ printed freight bill)**	**Why was the registration interrupted?**	**How long was the registration interrupted?**	**Sent documents to transporter**	**Delivered documents to warehouse**	**Print invoice**	**Sent customs declaration**	**Customs declaration approved**
0123456	01.02 – 14.15	01.02 – 14.25	Phone call	3 minutes	01.02 – 14.30	01.02 – 15.00	01.02– 14.20	01.02 – 13.15	01.02 – 14.15

NB: All orders must be filled out with both date and time.

8.1.3. Warehouse Office List

Order number	Print pick list	Start confirmation of picking	End confirmation of picking, printed sales shipment	Delivered documents to the office	Shipping the order
0123456	21.01 - 07.00	01.02 – 12.10	01.02 – 12.25	01.02 – 13.10	02.02 – 08.00

NB: All orders must be filled out with both date and time.

8.1.4. Warehouse List

				Fill out if interrupted during picking - important!			
Order number	**Pick list placed in shelf**	**Pick list taken from shelf**	**Start picking**	**Interrupted**	**Why was the picking interrupted?**	**Continue picking**	**End picking**
0123456	21.01 - 07.30	30.01 – 10.15	30.01 – 10.40	30.01 -12.00	Lack of products	01.02 – 11.00	01.02- 12.00

NB: All orders must be filled out with both date and time.

8.2. Results from the measuring of lead time

	International orders					Domestic orders	
	S-08540	S-08542	S-08562	S-08573	S-08721	S-08539	S-08541
Waiting to be registered	153		305	43	25	18	21
Registration in Navision	4		20	29	8	2	4
- Interruption	0		0	0	0	20	0
Electronic storage	536		148	37	3		0
Waiting + Transport to shelf	1	2	272	35	4		3
Storage in shelf	1678	410	5	62	0		2
Waiting to be picked	0	0	5	0	2	0	0
Picking	3	20		225	6	13	3
- Interruption	0	0		330	0	7	0
Waiting to start confirmation	2	27	4	2	4	58	0
Confirmation of picking	0,5	1	1	7	1	0,5	25
Sales s. stored in warehouse	42	47	5	6	5	2	2
Sales s. waiting in office	355	415	874	145			
Booking transport							6
- Interruption							0
Waiting to be shipped			60	120			

start	07.feb 08:15	07.feb 10:27	08.feb 15:10	10.feb 12:09	09.mar 16:54	07.feb 10:07	07.feb 10:37
finished office	07.feb 10:52		09.feb 13:05	10.feb 13:51	10.mar 08:33	07.feb 10:47	07.feb 11:02
finished warehouse	14.feb 09:14	09.feb 13:05	14.feb 10:55	14.feb 09:15	10.mar 08:58	08.feb 07:50	07.feb 11:37
end	15.feb 14:12	10.feb 14:35	16.feb 11:45	14.feb 14:20	10.mar 14:20	14.feb 14:00	07.feb 14:00
Total lead time	3125	1608	2615	1051	350	2483	173
Does the lead time include weekend?	Yes	No	Yes	Yes	No	Yes	No

Invoice date							10.feb
Shipped - invoiced							1260

	Domestic Orders						
	S-08544	S-08566	S-08568	S-08569	S-08570	S-08722	S-08724
Waiting to be registered	31	45	37	34	84	122	40
Registration in Navision	7	15	5	8	5	10	4
- Interruption	17	0	5	4	0	0	0
Electronic storage	40	207	1	418	101	442	1
Waiting + Transport to shelf	0	1	4	3	39	7	2
Storage in shelf	2	115	60	448	5	481	0
Waiting to be picked	0	0	25	0	0	5	1
Picking		47		67	25	10	6
- Interruption		0		0	310	0	0
Waiting to start confirmation	82	17	7	13	23	573	2
Confirmation of picking	1	3	1	2	1	1	0,5
Sales s. stored in warehouse	7	2	2	10	5	6	4
Sales s. waiting in office	898	273	0	45	1	268	
Booking transport	5	15	10	10	5	12	
- Interruption	2	0	0	0	0	0	
Waiting to be shipped	115	245	125	120	160	860	
start	07.feb 11:18	09.feb 13:30	10.feb 09:33	10.feb 09:48	10.feb 09:11	09.mar 14:43	10.mar 09:53
finished office	07.feb 12:13	09.feb 14:30	10.feb 10:20	10.feb 10:34	10.feb 10:40	10.mar 08:55	10.mar 10:37
finished warehouse	10.feb 11:30	10.feb 13:12	11.feb 11:50	14.feb 10:55	11.feb 11:19	15.mar 11:00	10.mar 10:53
end	14.feb 14:00	11.feb 14:35	11.feb 14:35	14.feb 14:20	11.feb 14:35	18.mar 07:05	10.mar 13:43
Total lead time	2442	985	742	1182	764	2413,5	200
Does the lead time include weekend?	Yes	No	No	Yes	No	Yes	No
Invoice date	16.feb	11.feb	11.feb	16.feb	11.feb	18.mar	10.mar
Shipped - invoiced	810	0	0	790	0	240	0

	Domestic Orders					
	S-08725	S-08726	S-08729	S-08730	S-08731	S-08736
Waiting to be registered	148	105	40	4	8	107
Registration in Navision	5	5	4	4	3	3
- Interruption	0	0	0	0	0	0
Electronic storage	70	83	178	19	48	11
Waiting + Transport to shelf	3	276	10		0	1
Storage in shelf	15	28	479		1	185
Waiting to be picked	0	2	45		5	17
Picking	15	298	15		15	11
- Interruption	0	0	515		0	0
Waiting to start confirmation	14	24	9		2	558
Confirmation of picking	1	3	1	2	1	1
Sales s. stored in warehouse	172	2	10	51	39	8
Sales s. waiting in office		1835	268	30	3	268
Booking transport		17	12	13	5	12
- Interruption		10	0	0	0	0
Waiting to be shipped		199	860	312	1223	860

start	10.mar 08:44	10.mar 10:03	10.mar 13:14	11.mar 07:10	11.mar 07:19	11.mar 11:38
finished office	10.mar 11:17	10.mar 11:53	10.mar 13:38	11.mar 08:08	11.mar 08:11	11.mar 13:58
finished warehouse	11.mar 08:07	14.mar 07:59	15.mar 11:00	16.mar 08:15	11.mar 10:12	15.mar 11:00
end	11.mar 13:47	18.mar 12:50	18.mar 07:05	16.mar 14:40	16.mar 08:13	18.mar 07:05

Total lead time	753	2887	2446	1830	1353	2042
Does the lead time include weekend?	No	Yes	Yes	Yes	Yes	Yes

Invoice date	11.mar	18.mar	18.mar	18.mar	18.mar	18.mar
Shipped - invoiced	0	0	240	770	227	240

	Domestic Orders				
	S-08587	S-08732	S-08735	**Average**	**# observations**
Waiting to be registered	155			**76,25**	20
Registration in Navision	5			**7,50**	20
- Interruption	0			**2,30**	20
Electronic storage				**130,17**	18
Waiting + Transport to shelf		1		**34,95**	19
Storage in shelf		5		**209,53**	19
Waiting to be picked		0		**5,35**	20
Picking		20		**47,00**	17
- Interruption		0		**68,35**	17
Waiting to start confirmation		22		**72,15**	20
Confirmation of picking		1	1	**2,57**	22
Sales s. stored in warehouse		5	2	**19,73**	22
Sales s. waiting in office			214	**368,25**	16
Booking transport			5	**9,77**	14
- Interruption			0	**0,92**	14
Waiting to be shipped			233	**392,29**	14
			Sum:	**1447,07**	

	Average	**# observations**
Total lead time	**1572,23**	20 *

*Total lead time is an average of lead times for both domestic and international orders

	Average	**# observations**
Shipped - invoiced	**326,93**	14

Process for international orders

Waiting to be registered	76,25
Registration in Navision	7,5
- Interruption	2,3
Electronic storage	130,17
Waiting + Transport to shelf	34,95
Storage in shelf	209,53
Waiting to be picked	5,35
Picking	47
- Interruption	68,35
Waiting to start confirmation	72,15
Confirmation of picking	2,57
Sales s. stored in warehouse	31,33
Waiting to be invoiced	548
Invoice	5 *
Invoice - customs	3,75
Customs declaration	9,5
Booking transport	9,79
- Interruption	0,86
Waiting to be shipped	392,29
Sum:	**1656,64**

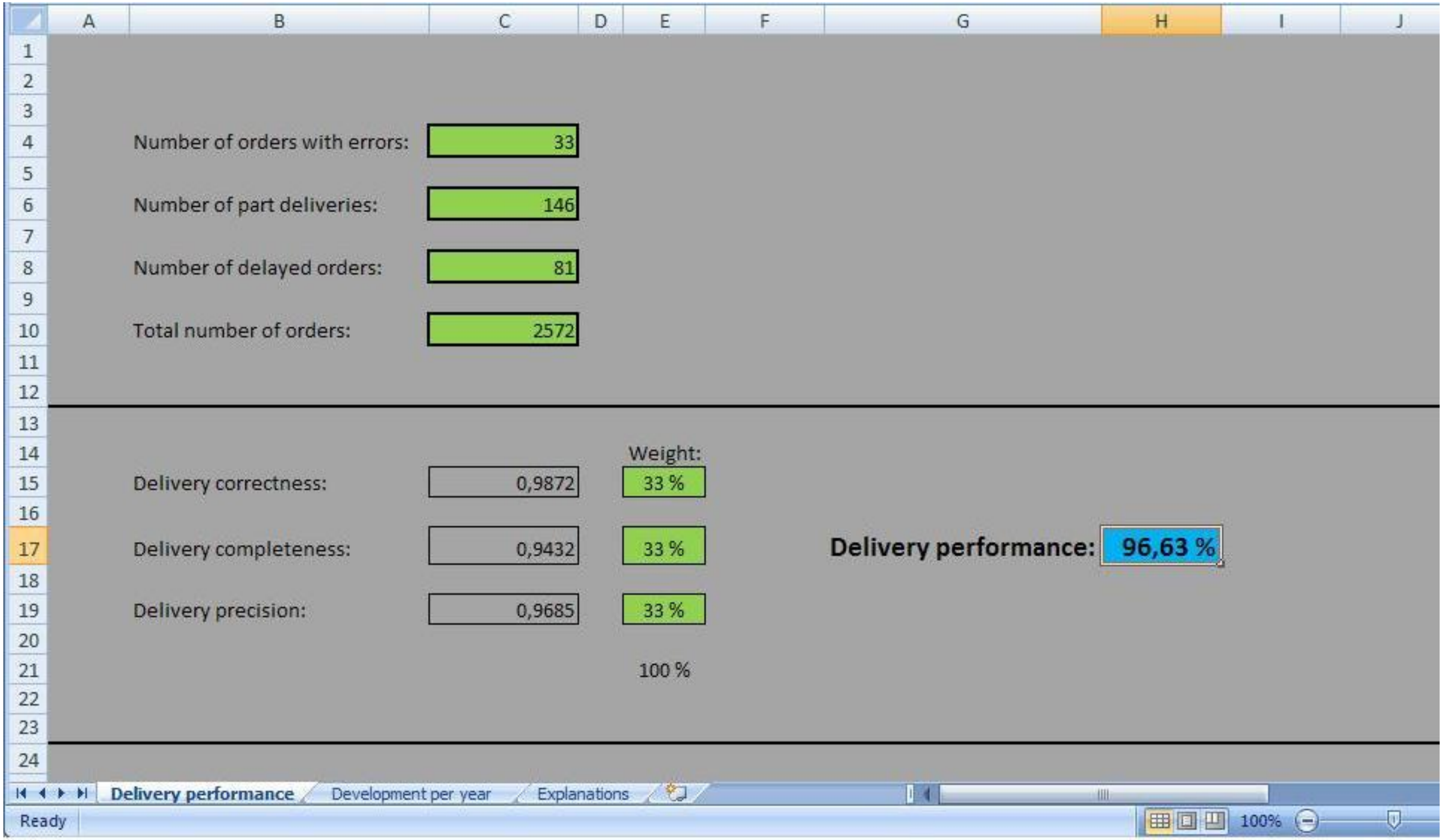
*not measured, but estimated by responsible person

International orders:	S-08540	S-08542	S-08562	S-08733	**Average**	**# observations**
Sales s. stored in warehouse	42	47	5		**31,33**	**3**
Waiting to be invoiced	355	415	874		**548,00**	3
Invoice - customs	4	5	1	5	**3,75**	4
Customs declaration	11	10	10	7	**9,5**	4

Total lead time domestic	1513,033
Total lead time international	1749,8

8.3. Screenshots from Excel tool for delivery performance

8.3.1. Sheet 1



8.3.2. Sheet 2

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of orders with errors:	14	17	22	33										
Number of part deliveries:	99	93	111	146										
Number of delayed orders:	58	46	66	81										
Total number of orders:	1646	2465	2365	2572										
Delivery correctness:	0,9915	0,9931	0,9907	0,9872										
Delivery completeness:	0,9399	0,9623	0,9531	0,9432										
Delivery precision:	0,9648	0,9813	0,9721	0,9685										
Delivery performance:	96,54 %	97,89 %	97,20 %	96,63 %										

Delivery performance | Development per year | Explanations

Ready 70%

8.3.3. Sheet 3

Concept	Definition
Number of orders with errors:	Errors that are registered in the log of errors and that include wrong number delivered, wrong article number delivered, labelling errors, delivered to wrong customer and wrong entered order
Number of part deliveries:	Orders that are registered with more than one invoice
Number of delayed orders:	Orders that have been delivered later than the agreed upon time.
Total number of orders:	The total number of orders during the time period.
Delivery correctness:	Indicates the share of orders that are delivered without errors
Delivery completeness:	Indicates the share of orders that are delivered completely, without part deliveries. This involves some inaccuracy since a part delivery not necessarily means that one has not been able to deliver
Delivery precision:	Indicates the share of orders that have been delivered at the agreed upon time, without delays
Delivery performance	Is calculated on the basis of the three elements above using the following formula: (Weight1 x Delivery correctness) + (Weight2 x Delivery completeness) + (Weight3 x Delivery precision)

Delivery performance | Development per year | **Explanations**

Ready 100%