SCHOOL OF ENGINEERING
JÖNKÖPING UNIVERSITY

Improving Efficiency of the Material Supply in Assembly Line

-A case study in the Automotive Industry in Southeast Asia

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Bachelor Thesis 2015

Industrial Engineering and Management, Logistics and Management

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This Bachelor Thesis was performed at School of Engineering at Jönköping University within the subject of Industrial Engineering and Management. The authors are responsible for the stated result, opinions and conclusions.

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Scope: 15 hp Bachelor level

Date: 2015-05-28

Abstract

Purpose – The purpose of the thesis was to improve the material supply for assembly line.

Methodology - The collected data were conducted through observations and measurements at the case company. Empirical data were analyzed and compared with the theoretical framework.

Result - Several non-value adding activities were identified in the case study that resulted in 88% of the total working effort. These non-value adding activities were classified into wastes referring to Liker and Meier (2006). Six different wastes were found: excess inventory, unnecessary transportation, unnecessary movements, defected products, waiting, unused and neglected resources. Improvement recommendations were proposed to increase the efficiency of the material supply.

Conclusions – There is at least one improvement proposal for every identified waste and combinations of these improvement proposals can reduce the non-value adding activities. Methods that can be useful to improve the material supply efficiency are change storage policy, reduce batch size, route plan milk-runs, implement standard work procedures and develop and integrate the information system. 5S and Kaizen are proposed theories that promote continuous improvements of the material supply.

Research Limitations – Since there are many factors affecting the material supply, more improvement proposals could have been found without delimitation of activities. This thesis is based on a single case study which leads to generalizable results for only companies with similar circumstances.

Further Research – By implementing the conducted improvement proposals a comparison of non-value adding activities is possible to strengthen the presented methods.

Key Words – Material Supply, Lean production, Non-Value Adding Activities, Wastes, Efficiency Improvements.

Contents

1. Introduction

This chapter will describe the background that makes the foundation of this thesis. After the presentation of the subject a more detailed problem description is composed. Then the purpose and research questions are presented that shows the aim of the study. The chapter is then finishing with delimitations that differentiate the focus and an outline which presents the structure of the thesis.

1.1 Background

The global business world is well aware of the fierce competitive environment in which they must manage their enterprises (Worley & Doolen, 2015). Currently prices are determined by different competitive market forces as opposed to before, when capacity constrained the sale volume (Srinivasan, 2012). Consumer's requirements are constantly severing with better quality, faster delivery time, and lower prices (Bukchin et al., 2002). The consumer's awareness of the fierce market leads to higher demand on product variety and specific properties. The internal logistics of supplying an assembly line with mixed needs are even more complicated (Faccio et al., 2013). For the last years Southeast Asia has grown significantly regarding production and export volumes. However, the local technology capacity, approached quality and input growth is something that have not exhibited as much in Thailand compared to the other countries (Doner, 2014).

To stay competitive companies have to improve their productivity and still offer a variety of products to a competitive price (Emde & Boysen, 2011). The productivity of a company can be improved by lean thinking, which has become the dominant technique used deliberatively to increase the productivity and profit to stay competitive (Demeter, 2010). The automotive industry has created a higher pressure to solve problems by converting from mass production to lean production (Womack, 1990). The Lean philosophy is an idealizing improvement approach which focuses on eliminating unnecessary activities to release time for value adding activities (Hines & Rich, 1997). Benefits earned by applying the lean approach includes delivering customer satisfaction, reduced inventory, reduced set-up times and increased quality (Womack, 1996). To accomplish that it is important to increase both operations'- and material handling efficiency (Srinivasan, 2012). Just-in-time (JIT) is one technique in Lean philosophy that is used to reduce inventory levels and time losses. This technique is focusing on supporting the assembly line or production with material in the right time and right quantity (Itir Satoglu & Ethem, 2012).

An effective material flow serving the assembly facility leads to reduced material handling costs and increased productivity (Kimberly, 2010). It also ensures the ability to adapt rapidly and successfully to changing situations. An efficient material supply is

needed to constantly serve the production or assembly line. The flow will affect the quality of supplies, reduce costs and obtain delivery assurance (Lumsden, 2012). An ideal material flow would be composed by a continuous flow including refining, but unfortunately that's not possible in practice. To manage different cycle times there have to be buffer stocks, these also prevent inevitable disruptions. Even if these are considered non-value adding steps, they are still necessary (Johnsson & Mattsson, 2011).

1.2 Problem description

Material supply aspects often have a low priority in industries and are often carried out as a final step after the layout has been completed. When improving the efficiency it's common to prioritize the production or assembly line and therefore the material handling process needs to be customized after the assembly line requirements (Johansson & Johansson, 2006). To focus on optimizing one single process in isolation is called local optimization. The lack of systems perspective promotes local rather than global optimization and can interfere with business growth. System thinking works by considering all the significant interactions the particular process has with all other processes. This is especially needed in the material handling process since it's depending on other processes in the system (Srinivasan, 2012). Up to fifty percent of the production related costs are connected to material handling activities, which makes it a very important factor when it comes to improve the efficiency (Green et al., 2010; Meyers, 1993).

Effective part feeding to the productive units has a direct impact on a company's productivity (Emde & Boysen, 2012). To successfully reduce overall material handling cost, the objective is to effectively receive, store and transfer goods (Kimberly, 2010). It is important to maintain a reliable and flexible material supply to minimize the risk of material lack and stoppages at the assembly line (Emde & Boysen, 2012). There are several important factors to consider when improving the material and inventory such as storage layout, incoming deliveries, and order picking (Lumsden, 2012). To accomplish efficiency improvements in the material supply its necessary to identify the process non-value adding activities such as material handling and internal transport of materials. If these activities can be determined and reduced the company's productivity can be increased. (Liker & Meier, 2006; Petersson et al., 2009).

According Klevensparr and Meivert (2014) further research concerning the material flow towards the assembly line are necessary. In present literature studies it is sparsely when it comes to application of lean practices in actual cases focusing on operator work (Scherrer-Rathje et al., 2009).

1.3 Purpose and research questions

As mentioned in background and problem description, the productivity has to constantly improve for a company to stay competitive on a fierce market, and to do so the company has to eliminate non-value adding activities (Liker & Meier, 2006). The purpose of this thesis is thereby formulated as following:

Investigate the applicability of lean production to improve the material supply for assembly line.

To achieve the purpose of this study, two research questions have been defined. The first step to reach an improved material supply process is to identify non-value adding activities. The first research question has therefore been established as following:

1. *Which non-value adding activities can be identified in the material supply?*

When the non-value adding activities have been identified it is important to reduce the non-value adding activities to concurrently improve the throughput of the material supply process. A better flow leads to enhanced productivity and improved efficiency, which leads to the second research question:

2. *How can these non-value adding activities be reduced to improve the material supply?*

These two questions are required to fulfill the purpose of the thesis. The first question is needed to get perspective of the assembly line, to be able to create a better flow in the value stream. The second question will suggest possible improvements to reduce time and cost. When the two questions have been answered the purpose will be fulfilled.

1.4 Delimitations

This thesis will focus on the material supply from incoming deliveries to the assembly line. Figure 1 shows a process chart including the process flow in the production plant. The orange colored process indicates the scope of this project. The material supply for one assembly line is delimitation where only the parts feeding that assembly line will be included.

Figure 1. Scope and delimitations.

1.5 Outline

The introduction of the thesis starts with a description of internal logistics background and why improving a production facility's efficiency is important. Then the problem description is formulated with focus on material supply and its impact on improving the efficiency of a company. Thereafter the purpose and research questions are defining the aim of the study. Delimitations are presented to show the scope of the study.

The second chapter, methodology, starts off with a description of the thesis work process, followed by the approach and methods used during the study. It gives a closer insight on how the collection of empirical data and theories, and also how the data has been analyzed and applied through the case study. At last the reliability and validity of the thesis is presented.

A theoretical framework is presented in the third chapter, which starts with a description of how it has been used to answer the research questions. The material supply and lean philosophy are then thoroughly described. Both methods and tools that been used are presented that efforts knowledge about how to improve the efficiency of the material supply.

Empirical data is the chapter that comes next which will describe the collected data from the case study made by collaboration with the company for this thesis. The case company present material supply process and different techniques that are being used now will also be demonstrated in the fourth chapter.

Chapter five to seven compose the result of the thesis. Presented in the fifth chapter contains an analysis of the collected theories and empirics. It will include an answer to the first research question with identification of insufficiencies in the material supply supporting the main assembly line. It will also include how these insufficiencies can affect each other.

An analysis of the empirical data collected through the case study will be included in the sixth chapter. In this chapter the second research question will be answered by using data compiled in chapter five, together with new empirical data and theories. The chapter ends with compiling an improvement proposal.

The seventh and finishing chapter begins with a discussion about the study including research questions and then the conclusions will be presented. A discussion and evaluation of chosen methods are then described in the chapter. Thereafter implications that occurred during the thesis work will be described. Finally suggestions of further research will be proposed.

2. Methodology

The chapter starts with an introduction on how the work process was conducted. This chapter defines the procedures used in this thesis to fulfill the purpose. It describes the methods used to collect and analyzed theory and empirical data and applied through the case study. Then the reliability and the validity of the thesis are described.

2.1 Work Process

To be able to answer the research questions suitable methods have been conducted to fulfill the purpose of the thesis. Figure 2 shows which methods that have been used for each research question.

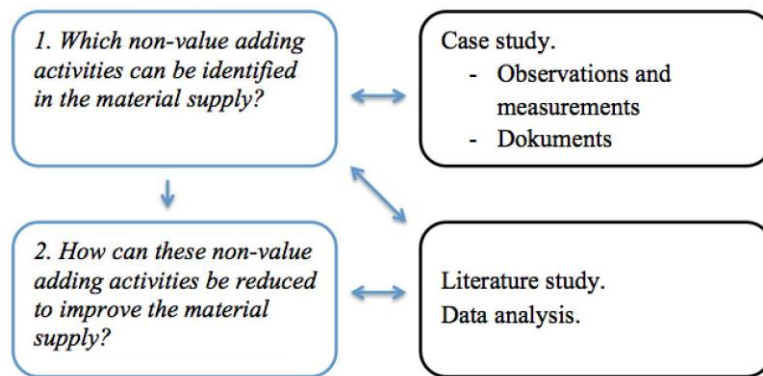

Figure 2. Connection between research questions and methodology

The duration of the thesis was five months; from January to May 2015. The work process was divided into five subprocesses with own timeframes, which are all illustrated in the Gantt-scheme (Figure 3). The subprocesses have been operating parallel with a balanced amount of work over time.
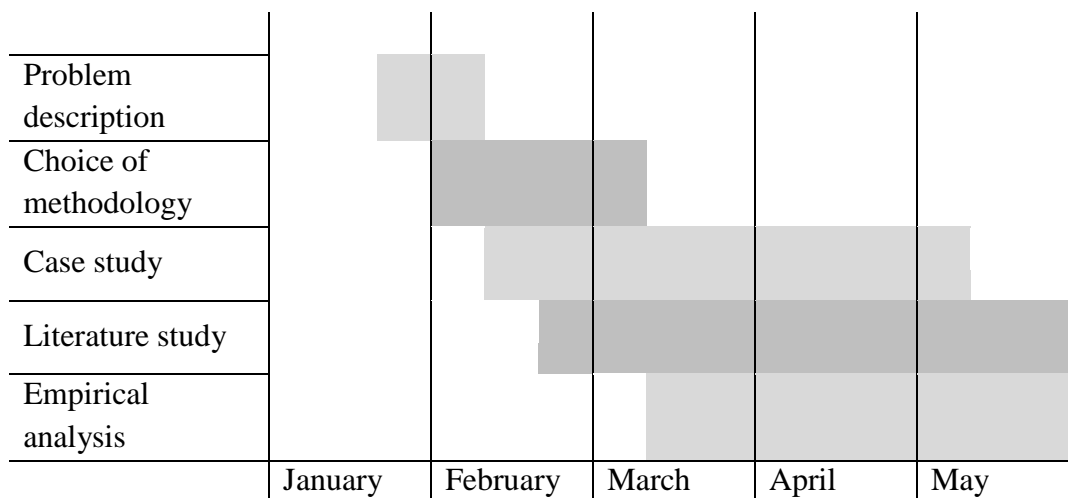

Figure 3. Timeframe during thesis work

The study was introduced by defining a problem description of the thesis. This was executed within settling purpose and research questions that aimed towards a generalized problem in the logistics department of the case company. Thereby a study aiming to receive a more efficient flow was designed. This within identifying the non-value adding activities in the material supply and reduce them.

After the thesis subject was determined the methods and strategies of the thesis was formed to answer the research questions and purpose. Different methods with the case company were discussed and the decided strategies were case study and literature study compare two different aspects to provide a firm result. This contains the statements of how the choice of methodology was grounded.

When the appropriate methods had been determined the data collection was made at a case company which contained measurements and observations of the different activities in the material supply for one assembly line. The case company was fully aware of their insufficiencies in the material handling processes and wanted to reduce the non-value adding activities.

The literature study was started shortly after the case study and they were later working parallel during the thesis. The literature study included studying different theories that could be useful. After the research the most important theories was chosen to receive answers to the research questions.

After the empirical data collection, an analysis of the result was conducted using the theoretical framework to be able to improve the efficiency of the material supply. Different aspects of the observations, measurements and theories were merged to receive a result of this thesis. This refers to the empirical analysis in the timeframe.

2.2 Research approach

The study concerns a specific empirical case where data and observations have been converted to existing general theories. The theoretical framework has been developed and updated when new empirics have been gathered from the case study. Theories have also been adjusted for the specific case. The literature study and case study have been under progress parallel which has led to support between the both studies (Saunders et al., 2012). Empirics and theories have been collected and analyzed repetitively during the study which according to Olsson and Sörensen (2011) is called an abductive research process.

The methodological approach used in the study has been pragmatic - both qualitative and quantitative. To answer the first research question have been collected to be able to

identify insufficiencies in the material supply. These empirics have been categorized using existing theories, which are called a quantitative methodological approach. The qualitative approach has been used to generalize the specific outcome of observations from the case company. A combination of a quantitative and qualitative method approach gives a better foundation for the result and analysis (Holme & Solvang, 1997).

2.3 Case study

A case study is a research strategy which focuses on obtaining an increased understanding of a subject. It's common using qualitative methods such as observations, but also quantitative methods such as studies of documents or measurements (Eisenhardt, 1989). According to Benneth (2003) applying gathered theories to answer research questions to a specific case is an advantage of using a case study, since it increases the validity of the thesis. There are two dimensions that should be taken into account: number of cases and number of units of analysis. The first dimension consider if it's a single or multiple case studies, the other dimension consider the number of units of analysis included in the research (Yin, 2007).

A single case study has been performed in the logistics department at the case company Volvo Group Trucks Thailand. The factory provides trucks to Southeast Asia which is very price sensitive and therefore continuous improvements of productivity are necessary. The factory contains several sections with different functions and the case study of this thesis is performed in the material supply of the assembly line that produces one of their truck brands UD. To receive a fulfilled purpose reliable data have been collected through own measurements and observations. To be able to improve the material supply several different theories have been analyzed and used for the study. The case study provided a broader knowledge about how to apply improvements in a real case using lean manufacturing and internal logistics methods to reduce unnecessary activities.

2.4 Data collection

Several different methods have been used to collect data to answer the research questions. A literature study was made to get a theoretical framework for the thesis. It was combined with a case study where data was collected by measurements, observations and documents.

2.4.1 Observations and measurements

Observation is a commonly used method to collect information about behavioral patterns in natural situations (Jacobsen, 2002; Patel & Davidson, 2011). In order to gather information to enable answering the research questions several observations were performed with different purpose (Table 1). The first observations were performed in order to get an overview of the case company including the main functions and the internal material flow layout. Thereafter two additional observations were performed at the assembly line to get an understanding of what insufficiencies was caused by the material supply. The first four observations can be described as unstructured, since the aim was to obtain as much information as possible concerning the problem area (Patel & Davidson, 2011).

Six separate measurements with observations were performed focusing on the material supply. Since the problem concerning the material supply is well defined with given situations, behaviors the observation performed can be referred as a structured (Creswell, 2009; Patel & Davidson, 2011). The measurements were obtained using time study when following three operators, two days each in the material supply department. The operating time for each activity performed during these days were measured. The formulary used during the measurements and observations are shown in appendix 1.

Table 1. Measurement and observations performed during case study.

Date	Time	What	How	Data
2015-01-22	4h	Production overview	Observation with menthor	Layout
2015-01-29	6h	Internal material flow	Observation with menthor	Material flow, work processes
2015-02-02	8h	Assembly line	Observations	Insufficiencies
2015-02-05	7h	Assembly line	Observations	Insufficiencies
2015-02-16	7h	Material supply	Observations & measurements	Operation times
2015-02-19	7h	Material supply	Observations & measurements	Operation times
2015-02-20	6h	Material supply	Observations & measurements	Operation times
2015-02-23	8h	Material supply	Observations & measurements	Operation times
2015-02-26	8h	Material supply	Observations & measurements	Operation times
2015-02-27	8h	Material supply	Observations & measurements	Operation times

2.4.2 Documents

Documentation from the case company has been analyzed to be able to answer the research questions. Documents containing information of storage layouts, production system model, takt time, storage planning and product structures. Documents were analyzed throughout the work process to be able to compare it with already gathered data. Documents were analyzed throughout the work process which gave the authors an insight of the case company.

2.4.3 Literature study

A literature study was made to get a better understanding of the subject and to set grounds for testing theories in the case study. The main focus of the literature study was on methods and techniques that could be used to achieve the aim of this thesis. The foundation of the theoretical framework has been gathered through literature studies within the fields of lean manufacturing and material handling. Lean manufacturing have been used to identify current situation of non-value adding activities. It also brings up several tools and techniques that can be used for improving efficiency, such as 5S and standard work. The literature concerning material handling are describing basic theories that helps defining the case company's current situation, but also information about principles that can be used to improve efficiency. These areas are both connected to the two research questions of the thesis.

The primary source used to find literature about the subjects was Jönköping University's library database, which was complemented with Google Scholar. The keywords used when searching were *material supply, material handling, lean production,* and *lean manufacturing.* Most of the literature studies consisted of scientific articles and textbooks. A comparison of the theories described in the literature was conducted to find common patterns in the articles and textbooks. The information gathered from literature studies and databases have been used as a support for the case study and the authors' conclusions.

2.5 Data analysis

The data analysis of collected theories and empirics was later conducted. The empirical data was compared with the theories to achieve a result, recommendations and conclusion. This led to easier identification of the non-value adding activities, and how to reduce them to improve the material supply efficiency.

All data was compiled and structured after the observation or measurement to ensure the accuracy of the analysis process. According to Backman (2008) later analysis of data can be simplified if collected data is structured and interpreted. The data collection and data analysis are sometimes hard to differentiate, which often makes the process

iterative (Jacobsen, 2002). This method enabled the authors to select what measurement techniques to be able to answer the research questions. The data was also compiled and simplified to provide a better understanding for the reader (Larsen, 2007; Patel & Davidson, 2011).

Empirics obtained by the measurements and observations have been structured in Microsoft Excel workbooks. The time study provided information about the material supply activities and their time requirement. These activities have been categorized by if they are providing value or not. Charts and calculations have been made to compare the large amount of quantitative data and provide distinct outcome for the improvement work. The summary of analyzed data can be found in appendix 2 and 3.

2.6 Reliability & Validity

To receive a dependable and useful result it is important to analyze how well the study has achieved reliability and validity. Validity secures the fact of how the result can be recognized in the practice (Merriam, 1994). Reliability means that the measurements have been performed correctly which means that if the measurement being repeated it going to relate to the same answer (Yin, 2003). Practical and theoretical data have been collected and analyzed to increase the reliability and validity of this study.

2.6.1 Reliability

Reliability indicates how dependable the measurement method is compared to the specific study. A high reliability involve the fact of that the same result is achieved for every measurement of the same operation (Patel & Davidson, 2011). To receive reliability for this thesis different of methods have been use to collected empirics of data, observations, and documentation (Yin, 2003). These methods are usually known as the triangulation and means that different sources are being compared to each other to build a stronger dependability (Burns, 2000). The observations in this thesis have been performed at the case company during eight working days in eight hour shifts. To strengthen the reliability of these study observations was done by following three operators in the material supply during two days each.

2.6.2 Validity

Validity involve that right things are measured concerning to the studies aim and scope. (Patel & Davidson, 2011). According to Andersen (1994) is validity a measured based on the study credibility which connects the theoretical to reality. In this thesis observations and measurements have been performed in the warehouse to be analyzed and compared to the theoretical frameworks to receive high validity (Yin, 2003). During the case study regular meetings with the logistics team at the case company have been perceived to check how the thesis and measurements being performed in the right way.

According to Leedy and Ormrod (2005) the external validity could be increased by a clear description about the connection between the case study and the result to be able to generalize the thesis.

3. Theoretical framework

This chapter includes theoretical components that form the basis of the thesis. The theoretical framework begins with a description of the relationship between the theories and the research questions. Lean manufacturing is presented with related theories, and the chapter ends with logistic theories that can lead to a more efficient material handling process.

3.1 Framework components

To achieve wider understanding a structural model of the theoretical framework has been composed. Figure 4 shows how the research questions are connected to the chosen theories that have been used to answer the purpose to this thesis.
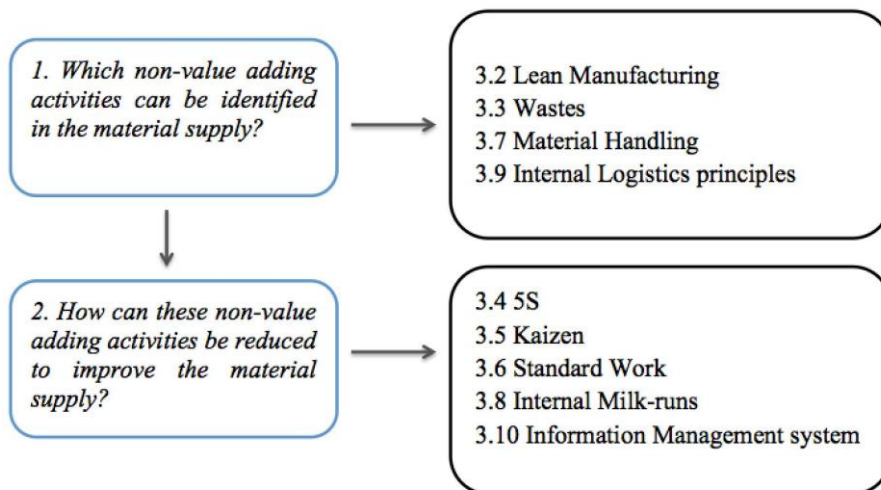
Figure 4. Theoretical framework components.

The first research question has been answered by the theories about *Lean manufacturing, wastes, material handling, and internal logistics principles. The second* research questions have been answered through theories regarding *5S, kaizen, standard work*, *internal milk-runs,* and *information management system.* These theories are all common in improvements work and are therefore used to answer research question two which have the purpose to reduce the non-value adding activities.

3.2 Lean manufacturing

Lean manufacturing is a strategy that focuses on eliminating waste from the value stream. (Alavi, 2003). A value stream is defined as all activities necessary to transform a product from raw material to finished goods (Womack & Jones, 1996). Waste is defined as non-necessary activity that adds no value for the customer. The benefits of

lean manufacturing includes reduced build time, increased quality, increased customer satisfaction, reduced inventory and reduced set-up times (Emiliani, 2001). JIT philosophy is deriving from lean manufacturing which have the focus to reduce non value adding activities, only produce after demanded quantitative, minimize the use of space and time, and improve the cycle time to the shortest as possible (Tompkins, 2010).

3.2.1 JIT

JIT has an increased amount of so called supermarket concepts. Supermarkets are areas that serve the nearby assembly line with parts (Faccio et al., 2013). Supermarket could be seen as in-house cross docking process where the parts are easier to handle for the picking operators. Supermarkets are a decentralized logistic system that divides parts to smaller boxes to frequently serve the assembly line (Boysen & Fliedner, 2010). If the supermarket frequently delivers small lots of parts it could minimize the storage volume near the assembly line and reduce the longer distance deliveries that are needed in other cases. To receive this fixed schedule and routes for the operators that serve a certain part of the system should be determined. From the supermarket the operators normally use small tow trains to pick the demanded parts and deliver these in appropriate boxes and collect empty boxes to the assembly station. When the deliveries have been made the operators pick up empty boxes and return to the supermarket to refill this and then go back to the assembly station (Faccio et al., 2013).

Point-of-use (PoU) storage is a technique that supports the JIT philosophy which contains the goals of reducing all unnecessary inventories from the factory floor and minimizes non-value adding transportation for the assembly operators (Macmillan J.M, 1993). Normally the PoU materials storage is located close to the production which allows quick access. The material is delivered in bigger batches of parts to a supermarket near the assembly line. Then small batches are being picked up from the supermarket to supply the PoU with materials for maybe just one product (Srinivasan, 2012).

3.3 Wastes

Wastes are the activities that create no value for final product and introduces unnecessary contingency and costs in the material flow. Wastes can be divided into eight different categories depending on where and how the waste is found (Lumsden, 2012).

Overproduction can be described as when a company produces more than the customer demand (Lumsden, 2012). Overproduction is considered to be a waste since unnecessary material is consuming a lot of storage space (Liker & Meier, 2006).

Waiting is waste of spare time spent waiting for necessary conditions (Petersson et al., 2009). Waiting occurs when workers are waiting for the next process step, tools, supply, part, etc. It could also be workers merely serving to watch an automotive machine or having no work because of stock outs, lot processing delays, equipment downtime, and capacity bottlenecks. (Liker, 2004)

Excessive Processing implies more work than the customer are demanding or are willing to pay for and are therefore defined as a waste (Petersson et al., 2009). It is due to poor tool and product design, causing unnecessary motions and producing defects.

Unnecessary Movements indicates wasted motions employees are performing such as looking for, reaching for, or stacking parts, tools, etc. Walking is also a significant waste that should be taken into account (Liker, 2004).

Unnecessary Transportation are when carrying work in process (WIP) long distances, creating inefficient transports, or moving material, parts or finished goods into or out of storage or between processes (Liker, 2004). Transportations are a non-value adding process except for transport to the end customer (Petersson et al., 2009).

Excess Inventory can be raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, extra inventory hides problems such as production imbalances, late deliveries, defects, equipment downtime and long setup times (Liker, 2004).

Defected products are a waste when the product quality is defective which leads to reparations and corrections. Repair, rework, scrap, replacement production, and inspection imply wasteful handling, time, and effort (Liker, 2004).

Unused or Neglected Resources are one of the most common wastes, where the available resources are not utilized or utilized in the wrong way (Lumsden, 2012). This

also includes when workers' experience and competency are not utilized (Liker & Meier, 2006).

3.4   5S

The aim of 5S is to create a business environment that enables efficiency and productivity (Bergman & Klefsjö, 2012; Liker & Meier, 2006). The 5S is five Japanese words which stand for sorting, set in order, shine, standardize and sustain (Ho et al., 1995).

Sorting - Sorting is the first step of 5S with the aim to eliminate the unnecessary items from the workplace. Items that are rarely used are moved to a more organized storage area outside of the working area and items which are unnecessary are disposed from the organization (Peterson & Smith, 2001). According to Harrington (2000) sorting helps eliminating broken tools, scrap and obsolete jigs and fixtures. Sorting helps eliminate wastes such as unnecessary movements and waiting time (Liker & Meier, 2006).

Set in order - The focus of set in order is segregation of things and effective storage (Harrington, 2000). This area includes labeling items, using color system for quick recognition, storing similar items together, storing different items together, using names and numbers on everything, painting floors and using a rack or shelf and shadow boards for tools. Arranging items in the right place will make jigs, fixtures, tools and other resources detectable, noticeable and easy to use (Dudek-Burlikowska, 2006; Lancucki, 2001).

Shine - The third S brings up the cleaning activities in the organization and how daily cleanliness is important to improve work area, which makes the workplace more comfortable and safe (Peterson & Smith, 2001; Harrington, 2000). A clean and organized work area itself acts as a motivation factor for the employees; employees enjoy their work in a clean and healthy environment which boosts up their confidence. It also leads quality achievement for the company (Dudek-Burlikowska, 2006). Cleanliness has to be maintained without pressure, the employees have to make it a natural habit. Standards are often used to ensure that the cleaning is followed effectively (Lancucki, 2001).

Standardize - The high standard of workplace can be ensured by standardization (Peterson & Smith, 2001). The employees play a great role in developing these standards. Every employee knows their own responsibilities, and other duties are performed in a regular routine. The standardized approach should be seen as an agreement of how work should be performed (Petersson et al., 2009). Audits have to be held regularly and scores should be assigned for areas of responsibilities (Gupta, 2015).

Sustain - Sustain is considered to be the toughest to implement. Many firms implement the 5S activities, but it becomes very difficult to sustain the activities performed (Peterson & Smith, 2001). Standards have to be maintained in an effective manner in longer term (Harrington, 2000; Dudek-Burlikowska, 2006). Counseling of the employees should be done regularly and proper discipline should be maintained. Award and reward system is also important to motivate the employees. That could lead to both financial gain and formal presentation of a certificate (Lancucki, 2001).

3.5 Kaizen

Continuous improvement has been used to acquire competitive advantage and is inherent in many manufacturing management philosophies such as Theory of Constraints (Goldratt & Fox, 1986) and Six Sigma (Pande et al. 2000). Kaizen is an approach in lean production, which has attracted a considerable interest in continuous improvements (Imai, 1986). The technique of Kaizen is continuous searching for improvements (Imai, 1986). Kaizen is focusing on employee involvement can be received by education and creating opportunities to improve the work system (Minton, 1998) and emphasize to low-cost changes to improve performance. Kaizen events are also focusing on to address errors and other quality related issues (Melnyk et al., 1998).

3.6 Standard work

Standard work or standard operating procedure relates to a clear specification of how tasks should be performed. After determining the manual operation time or cycle time for each operation a task sequence including the combination of resources are calculated and documented. The order of actions that the worker must perform within a given cycle time must be defined. This allows processes to be completed in a consistent, timely, and repeatable manner to eliminate variability and concurrently improve the throughput of the workstation (Monden, 1993). With established standards performance is measurable. Standard work promotes both consistency and continuous improvement, since it is difficult to improve a process if each operator performs tasks differently. The aim with setting standard work is to give each operator an amount of work less than or equal to the takt time while creating a compact footprint for each operator (Srinivasan, 2012).

3.7 Material handling

The material handling process includes handling and checking incoming gods, internal transportations of goods, storing, picking, packing, marking and consigning goods

(Öjmertz, 1998).The goal of the handling processes is to conceive the right material in the right place in right time. The material handling is affecting both cost and delivery services depending on how the different operations is being performed. A non functional picking operation could lead to lack of material in the assembly line which could affect the promised delivery time (Oskarsson et al., 2006). Emballage are used as protection for the material and can also make efficient handling and storing possible then it is easier to handle and identify the material. For small sized articles, plastic boxes are preferable since movement becomes more ergonomic within enabling easier handling, and it is also space saving (Johnsson & Mattsson, 2010).

3.7.1 Reduce Batch Size

Reduce batch size is another alternative to reduce wastes of excess storage. Higher quantities at the PoU often cause damaged goods at the case company, and it is also space consuming. By reducing the batch size to PoU the company will be able to minimize WIP (Lumsden, 2012). By using smaller buffers quality shortages can be noted earlier in the process (Bergman & Klevsjö, 2014).

3.7.2 Material Quality

By improve the quality of internal processes, the inventory can be reduced. A high internal quality of the expected results can be named lean (Bergman & Klevsjö, 2014). If defective articles aren't discovered in an early stage it can create valueless work and quality shortages on products that lead to increased cost (Lumsden, 2012).

3.7.3 Materials feeding

The material feeding principles refer to how raw material and components are delivered and presented in the manufacturing (Hanson, 2012). Johansson (1991) describes three different principles of feeding materials to an assembly station: continuous supply, batch supply and kitting. These are categorized with regards to whether a selection of part numbers, or all part numbers, are displayed at the assembly station and whether the components are sorted by part numbers or assembly objects (figure 5). There are two factors that influence the choice of materials feeding principle for components: the number of parallel flows in the assembly line and the characteristics of the assembled product (Johansson, 1991). Since the case company only had continuous supply and kitting these are the ones presented in the thesis.

	Selection of part number	All part numbers
Sorted by part	BATCH	CONTINUOUS
Sorted by assembly object	KITTING	

Figure 5. Material feeding principles (Johansson, 1991).

Kitting implies that parts are delivered and presented to the assembly station in pre-sorted kits where each kit contains parts for one assembly object. Often each kit is delivered and presented in some form of carrier, such as a box or a trolley. The kit can be presented in a stationary position at an assembly station or, in case of assembly along an assembly line; the kit can travel with the assembly object along the line (Bozer & McGinnis 1992). A disadvantage of kitting is that the internal transportations at the plant are increased. If the material is fragile kitting isn't preferable since the risk for damage is increased when repackaging (Hanson & Medbo, 2012).

Continuous supply is when small quantities of a larger amount material are transferred from storage to assembly line. The material is then refilled when the pallets are empty which ensure that the material always is accessible (Johnsson & Mattsson, 2010). When continuous supply is used, each part number is presented separately at the assembly station. This can often be achieved using the original packaging, which means that repacking is not required. Part number specific unit loads are delivered to the assembly line from storage or directly from a supplying process. If the space is limited, repacking to smaller unit loads may be required (Johansson, 1991).

3.8 Internal Milk-run Distribution System

It requires long-term planning to select the most efficient route (Wilson et al., 1996). Milk-runs can be used both external and internal when planning transportations (Baudin, 2004). To determine routes and their time periods Kilic et al. (2012) have developed three different categories that can be used. The first category is called *General Assignment Problem* that is used when routes and time aren´t known. The category includes two different alternatives; one routed and multiply routed vehicles and these are divided into differently and equally timed routes. *Dedicated Assignment Problem* is when groups of cells or stock points are already determined which means that the routes are known but the time period and the vehicles on the related tours have to be determined. Even this category is divided into differently and equally timed routes. *Determined Time Periods Assignment Problem* is milk-runs with known time period, but the routes are not. This category can be sorted into one routed and multiple routed vehicles.

3.9 Internal logistics principles

Picking principles, storage principles and routing principles are all internal logistics principles that have influence on the material handling process. Picking principles have been used to describe empirical findings and storage policies have been used to improve the efficiency of the material supply. Routing policies have not been used in the thesis when another route planning theory has been applied instead.

3.8.1 Picking principles
There are four principles for manual picking when operators are walking to the material. How to pick depends on number of orders per purchase order, and the number of units per order. (Johnsson & Mattson, 2011). *Strict-order picking* is the first principle where the operator completes a route by picking all stock keeping units (SKU) for a single order. The second principle, *first-come-first-served*, are used when batching the maximum number of orders (Petersen, 2000). The third policy is *bin-packing* which a more complex batching technique that consider both size and product volume (Ruben & Jacobs, 1999). *Zone picking* is the last policy that divides the warehouse into zones and gives the picking operators assignments within a single zone (Petersen & Aase, 2004).

3.8.2 Storage principles
Storage policies assign SKUs to storage locations, which generally are divided into three sections. SKUs may be assigned randomly, grouped into categories with similar SKUs that are placed in the same area of the warehouse, or assigned to a location based on demand or volume. *Random storage* is common in many warehouses because it is simple to use, and requires less space than other storage methods, which results in increased utilization of all picking aisles. *Volume-based storage* policies assign SKUs

with the largest demand to locations near the pick-up/drop-off point. Research shows that a within-aisle implementation of volume-based storage significantly reduces travel time (Jarvis and McDowell, 1991; Petersen & Schmenner, 1999). *Class-based storage* with as few as three storage classes provides nearly the same savings as volume-based storage in an automated storage and retrieval systems while requiring less data processing (Eynan & Rosenblatt, 1994).

3.10 Information Management System

Poor communication can lead to unnecessary working effort and overall work aggravates (Petersson et al., 2009). Information Management Systems are used to support planning and logistic flows (Johnsson & Mattsson, 2010). The quality of an information system is related to customer satisfaction (Boehm et al., 2008). The advantages with an information management system are that common databases and consistent cross-functional information could allow the organizations to integrate information with different department and location which increase the efficiency of the processes on the company (Hong & Kim, 2002).

4. Material Supply at the case company

This chapter presents the empirical data gathered through the case study. An introduction of the case company will be presented followed by a description of the material supply process. Complementing empirical data will be further presented in chapter five and six together with the result and analysis.

4.1 Case Company

The case study was performed at Volvo Group Trucks Thailand, part of Volvo Group who is one of the world's leading manufacturers of trucks, buses and construction equipment. The company is globally spread with production facilities in 19 counties, where Thailand is one of them (Volvo Group Global).

Today the factory produces three trucks per day, however the demand is fluctuating. Since the case company produces customized products the product range is very wide. Within the production of UD Trucks an assembly line with twenty four stations is combined to supply the demand. The case study was performed to identify non-value adding activities to investigate improvements that could lead to efficiency benefits for the material supply. Improvements of the efficiency are needed to stay competitive in a fierce market.

4.2 Material Supply Overview

The material supply process includes several different activities, load carriers, and storage systems. These are all different variables that influence the performance of the material supply. Figure 6 illustrates the facility layout concerning the material supply at the case company.

▽   - PoU
●   - Assembly station
           - Storage
           - Supermarket
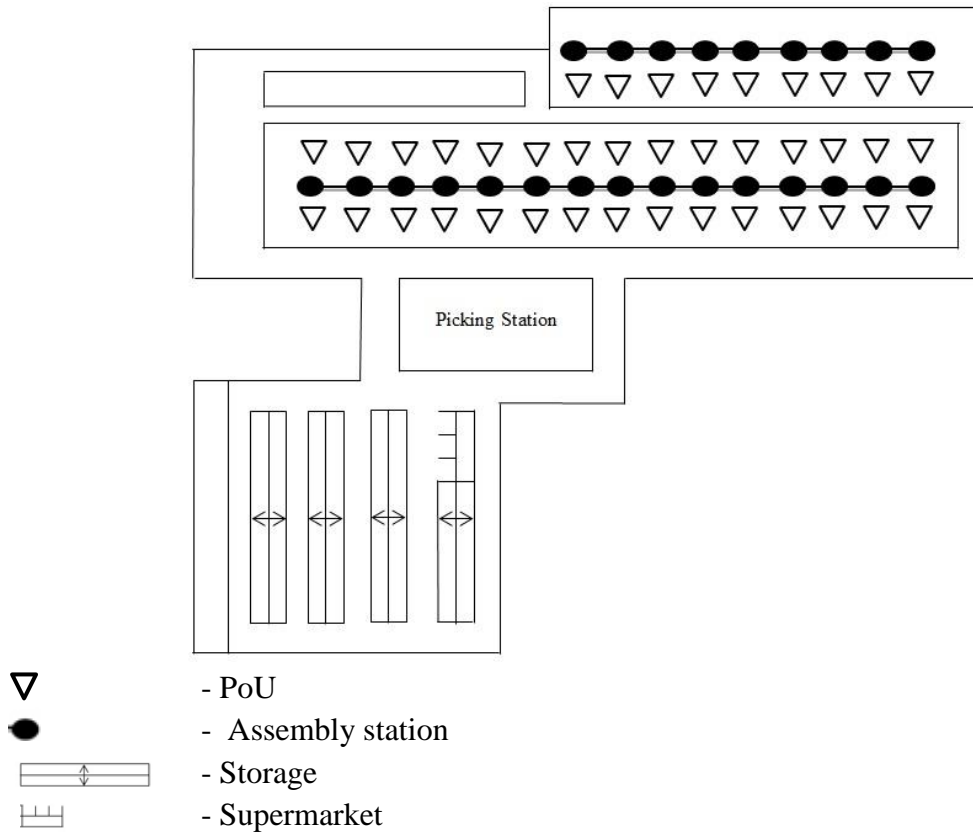
Figure 6. Facility layout.

Products in the warehouse have determined locations in the rack and the operator are allocating the pallets in storage by part number and thereby the storage policy is dedicated. Since the time and routes are unknown in the material supply the internal transportation are identified as General Assignment Milk-runs.

4.2.1 System- and process declaration

Different kinds of load carriers are used depending on size, weight and demand. The load carriers used at the case company are pallets, plastic boxes, carton boxes and racks. Pallets are used when inbound materials are stored before kitting and picking operations. The replenishment in the material supply is formed as the operator searching for empty carriers. The operator refills carriers when they are found empty in the PoU. The inventory is divided into two different categories; higher shelves are for storing material and the lowest shelf is for picking. To be able to pick products in the material

supply the case company used their lowest shelf as kitting location where they refilled pallets frequently. At the case company the orders are large and the picking is divided into three zones, one for each picking operator. The different zones are main assembly line, sub line, and supermarket. When empty pallet is found in the kitting location in the storage or the quantity in pallet is not sufficient with quantity in order, replenishment is performed. Thereafter the picking operators pick articles onto carriers that contain maximum two days demand.

The PoU storage is placed close to the assembly line to provide the operators with the right material in the right time. All articles that will be a part on the trucks are placed in the PoU storage. The bigger parts are is placed on carriers and the smaller parts into the supermarket. The Supermarket system in the PoU storage includes plastic boxes and carton boxes that are used for smaller parts accessible at the supermarkets. When these blue boxes or carton boxes become empty the operator gets the empty carriers and replenishes them in the material supply inventory. The transportation to the assembly line from the material supply can differ from time to time depending on how many carriers the operator brings and the number of different locations that need to be visited. The routing route of the assembly line is formed in a U-shaped layout. Mostly of the operator just take one or two rack to the assembly line and sometimes more. The transportation in the material supply is also varied and sometimes picking operation is connected to nearby locations. It also happens that the picking operations can be kind of disorganized then the operators can shift to a storage shelf to another and then back to the first one.

4.2.2 Material Supply Activities

There are several activities that are included in the material supply process. All activities found in this case study through the measurements and observations are presented in figure 7 below. Appendix 2 presents a deeper summary of the activities performed by each operator.
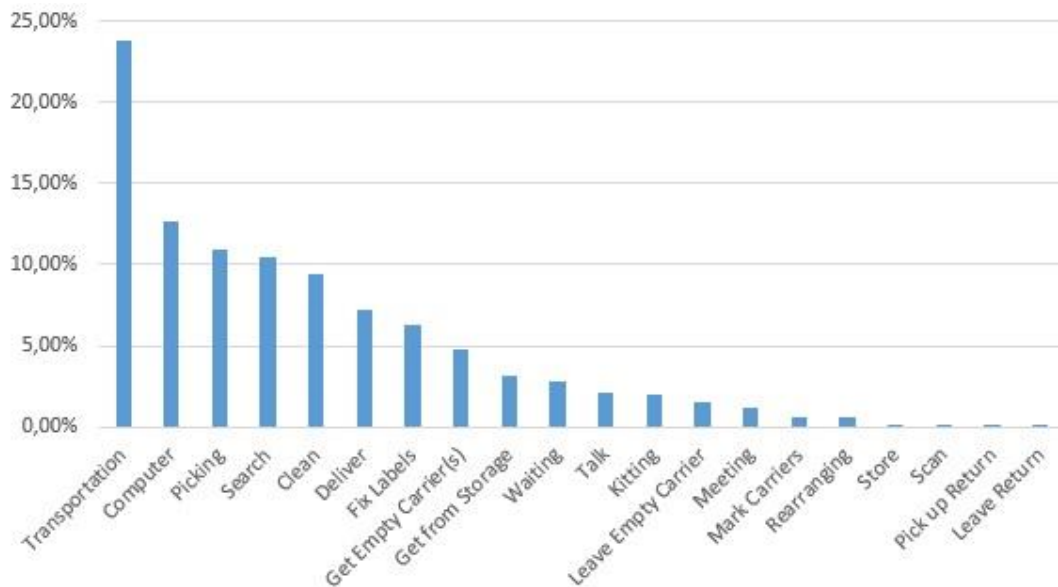
Figure 7. Activities and their weight.

One of the basic activities is for the operator to get pallets from storage using forklift. Sometimes the pallets are moved to another location in the storage which is called *Store*, but when the operator are leaving goods at the assembly line or kitting location it is mentioned in the report as *Deliver*. *Transportation* is the most commonly practiced activity which is the movement between locations in the facility with or without articles. When the operator finds empty carriers at PoU during transportation, the carriers are picked up and are brought back to storage which is called *Get Empty Carriers*. The operators *Leave Empty Carriers* in the warehouse until a refill in the PoU is necessary. *Search* includes when operators are actively searching for empty carriers at PoU or in the kitting location, but also looking for the right picking location or understanding the information given in the scanner.

The *Kitting* activity is when the operator moves material from a pallet to another pallet in kitting location at the lowest shelf. *Picking* implies the activity when the operator picks a certain number of one or more parts to load an empty carrier. The picking operation starts when the tow train stops in the right location and continues until the operator has picked the material and attaches the empty carrier to the tow train. After the picking or kitting activity the operator *Scan* the part number to get a confirmation into the system. One activity only performed at the supermarket is when the operator

picks several boxes and marks the different locations where they are demanded and that is called *Mark carriers.*

Cleaning includes sample cartoon pieces after a broken pallet or to remove dust in the material supply and in the assembly line. *Rearranging* includes reaching pallets that are placed under or behind other materials. It is also when the operator switches tools or organizing materials. When the aisles are blocked with emballage the operator needs to clear the way before continuing. When damaged or nonfunctional products are found in the assembly line the operator from the material supply *picks up the return*. The operator leaves the damaged product by the picking station where a damage report has to be confirmed by a person in charge. Thereafter the product is placed in a shelf with damaged or nonfunctional products called *Leave Return.* Another activity is when operators work on the *Computer*. Activities like making orders and checking information about materials is some of the working task that is performed. The operators working tasks also includes printing labels, cut labels and replace old labels and that is mentioned as *Fix Labels*

Sometimes the operator is standing still and waiting to take action and that activity is called *Waiting*. It could be different causes of the waiting activity such as someone or something is blocking the way or the operator waiting for orders or information. The operators attend to *Meetings* every Friday afternoon with the whole production unit. They also have smaller meetings on Friday mornings with their material supply unit. Another activity is when the operator *Talks* to colleagues, which could be both job related or not.

5. Non-value adding activities

This chapter presents an analysis where the empirical data are compared and categorized depending on known theories to answer the first research question. A value analysis will be shown with empirical illustrations from the case company. In the end of the chapter a waste classification are presented.

5.1 Value Analysis

To accomplish efficiency improvements in the material supply it is necessary to perform a value analysis. If the value adding status can be determined the non-value adding activities can be reduced and the company's productivity increased (Liker & Meier, 2006; Petersson et al., 2009). The value analysis performed in the case study gave following result shown in figure 8 and further details are found in appendix 3.
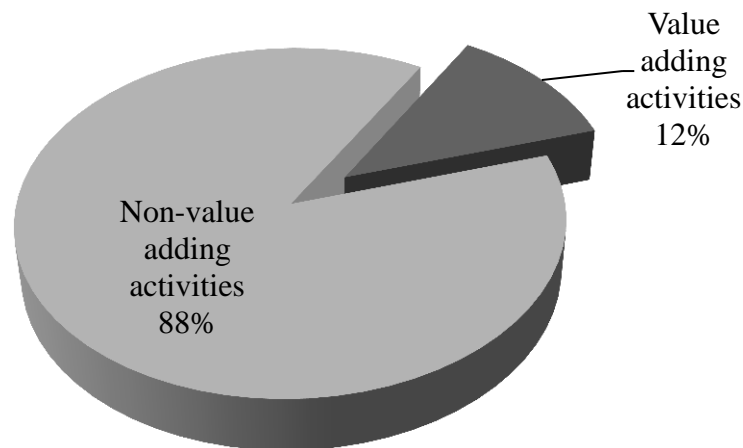
Figure 8. Percentage of material supply activities.

In lean production, the assembly operator is focused on performing only value adding activities from the customer's perspective (Liker, 2004). The materials feeding should serve the assembly operator and ideally cater requirements without need for the operator to move away from the assembly object (Baudin, 2004). The picking and kitting operations are subscribed as value adding activities. The picking and kitting activities contributes value for the customer when the operations are refining the end product. Non-value adding activities are the activities that were performed in the production where no refining is being done. The non-value adding activities can be distinguished as both necessary and unnecessary activities (Hines & Rich, 1997).

5.2 Waste identification

The non-value adding activities that were discovered in the case study have been classified into six wastes. The study has been conducted from Liker and Meiers' (2006) eight wastes. The wastes that have been detected at the case company are presented in figure 9. The identification could maximize the customer value and minimize the operational wastes (Sternberg et al, 2012).

Unnecessary Transportation   Excess Inventory   Unnecessary Movements   Excessive Processing

Defected Products   Overproduction   Waiting   Unused or Neglected Resources

Figure 9. Identified wastes.

5.2.1 Excess Inventory

Excess Inventory can be raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay (Liker, 2004). A problem at the case company is that the operators sometimes deliver more articles in PoU than determined. The case company has limited storage space and therefore improvements of the occupancy level are important to increase available storage. To decrease the risk of damaged goods and higher storage cost the quantity of materials in storage should be as small as possible (Liker, 2004). To be able to maximize the total efficiency both storing and handling have to be considered (Lumsden, 2012).

5.2.2 Unnecessary Transportation

Unnecessary Transportation are when carrying work in process (WIP) long distances, creating inefficient transports, or moving material, parts or finished goods into or out of storage or between processes (Liker, 2004). Transportation is the largest activity of all and comes up too nearly twenty four percent of the total working time in the material supply at the case company. These wastes consist of several long transportations with low number of carriers and have no certain routines. This affects the utilization rate negatively since the carriers have a higher capacity than is used. When resources utilization rate is low the process cost is divided by fewer articles, which leads to a higher unit cost (Johnsson & Mattsson, 2010).

5.2.3 Unnecessary Movements

Unnecessary Movements are a collection of motions such as looking for, reaching for, or stacking parts, tools, etc. (Liker, 2004). At the case company the searching activity represents more than ten percent of the total work in the material supply. This activity contains unnecessary movements such as walking to find tools, colleagues or information. The position of tools and materials can lead to unnecessary movements (Petersson et al., 2009). Another walking waste occurred when the operator couldn't transport racks with tow train because of defected carrier, so that the operator had to walk with the rack. The last identified waste is unclear labeling of the carriers regarding quantities, part number, and location which lead to unnecessary movements when searching for correct information. All these unnecessary movement is a waste of time and should be reduced or if possible eliminated (Lumsden, 2012).

5.2.4 Defected Products

Defected products are a waste when the poor product quality leads to reparations and corrections (Liker, 2004). In the material supply defected articles can cause unnecessary activities such as pick up, transport and leave returns and pick new parts to deliver by the assembly line. To send forward defected articles in the value stream is pure waste and should be avoided. Several products were found with quality defects in carriers containing high volumes in the PoU. If defective articles aren't discovered consequences like valueless work and quality shortages can occur that increase costs (Lumsden, 2012). The operator at the case company has to walk through the inventory to get the damaged goods report approved by their unit manager.

5.2.5 Waiting

Waiting occurs when workers are waiting for the next process step, tools, supply, part, etc. (Liker, 2004). Three percent of all the activities are pure waiting for the material supply at the case company. Waiting occurs when workers were waiting when someone or something is blocking the way or when the operator is waiting for orders or information. It also occurs in the searching activity when the operator are looking for the right location which leads to that the material handling process becomes less effective. Waiting is a waste of human resources and time, which leads to extended lead time (Lumsden, 2012).

5.2.6 Unused or Neglected Resources

Unused or Neglected Resources are one of the most common wastes, where the available resources are not utilized or utilized in the wrong way (Lumsden, 2012). This also includes when workers' experience and competency are not utilized (Liker & Meier, 2006). Unused resources in the case study were when operators had no permission of certain working tasks and therefore another operator had to perform the task. Neglected resources occurred at the case company when the picking operators were cleaning the storage and the assembly line instead of serving the assembly line.

Cleaning made up more than nine percent of the working time in the material supply. Both unused and neglected resources are wastes of human resources since they are used inefficient (Lumsden, 2012). According to Liker (2009) another important waste is when companies are missing ideas and improvements as a result of corporate culture with lack of employee involvement.

6. Efficiency improvements

This chapter provides answers to the second research question with emphasis on reduction of non-value adding activities classified as wastes. Several methods are presented together with their influence on each waste to improve the efficiency of the material supply.

6.1 Reduction of non-value adding work

To improve the efficiency of the material supply the non-value adding activities should be reduced (Petersson et al., 2009; Segerstedt, 2009). This chapter presents several efficiency improvement methods that can be used to reduce these activities. In table 2 the suggested methods are introduced with their possible impact on the non-value adding activities.

Table 2. Methods to reduce non-value adding activities.

Wastes Improvement Proposals	Excess Inventory	Unnecessary Transportation	Unnecessary Movements	Defected Products	Waiting	Unused Resources
Storage policies	✓	✓				
Route Plan the Milk-Runs		✓				
Reduce Batch Size	✓			✓		
Information Management System		✓		✓	✓	
5S			✓	✓	✓	
Kaizen				✓		✓
Standard Work		✓				✓

6.1.1 Excess Inventory

To decrease the risk of damaged goods and higher storage cost the quantity of materials in storage should be as small as possible (Liker, 2004). To maximize the total efficiency both storing and handling have to be considered (Lumsden, 2012). When improving the efficiency different *storage policies* can be considered. The storage policy used today is dedicated which means that the products have determined locations in the

inventory. Since the storage space is limited the company should consider alternate policies that claim less space. The class-based policy stores the products randomly in a class, resulting in storage space saving due to complementarities of demand of products (Francis et al., 1992).

The material supply at the case company are using two days lead time in PoU, but sometimes the picking operators exceed that limit. Higher quantities at the PoU often cause damaged goods at the case company, and it is also space consuming. *Reducing batch size* is an alternative to minimize cost caused by WIP in PoU (Lumsden, 2012).

6.1.2 Unnecessary Transportation

When resources utilization rate is low the process cost is divided by fewer articles, which leads to a higher unit cost and the number of transportation increases (Johnsson & Mattsson, 2010). By changing *storage policy* the company could reduce unnecessary transportation. According to Malmborg (1996) the reduction of storage space could be sufficient to improve the travel distances. Muppani & Adil (2008) perceived conclusions that the class-based policy may yield lower travel distance than the dedicated policy. Picking frequency or location in assembly line are two characteristics that would be appropriate for the case company. By locating frequently used articles close to assembly line the transportation of the most frequent articles would be reduced. The articles with same location in PoU could be stored in the same class to easily coordinate picking and transportation.

Route plan the milk-runs is also one alternative to reduce transportations. The mission of route planning is to minimize driving distance, number of routes and vehicles and to maximize number of delivered articles per operator and also the utilization level. By coordinating the transportations the total number of transportations can be decreased and thereby increase the profitability (Lumsden, 2012). At the case company the majority of all transportations are going around the whole assembly line which could be referred to as a general assignment problem. The general assignment method can affect the idle time negatively and therefor route plan milk run could be a solution. By coordinate and pick carriers to deliver in the same area, the transportations doesn't have to go around the assembly line in every route. According to Kilic et al. (2012) multiple routed tow trains can reduce idle time and number of vehicles. The goal is to minimize the cost of WIP and the internal transportation cost.

With an integrated *information management system* in the warehouse the case company could share and receive information. The information system should provide the operators with correct information, assignments, and routes which could reduce the transportation, search, and computer activities. By establishing *standard operating procedure*s both planning milk-runs and implementing an information system would be simplified. According to Monden (1993) standard work allows processes to be

completed in a consistent, timely, and repeatable manner to eliminate variability and concurrently create a better flow at the workstation. Determination of the manual operation time for each operation enables planning the milk-runs and to share correct information. Another advantage of standard work is that the operators work efficiency is measurable since standards are established (Srinivasan, 2012).

6.1.3 Unnecessary Movements

All unnecessary movements are a waste of time and should be reduced or if possible eliminated (Lumsden, 2012). According to Liker & Meier (2006) these wastes can be reduced by sorting, set in order and standardize which are three of the five steps in *5S*. The first step in 5S is sorting which will help to eliminate broken tools such as defected carriers. With 5S all defected items will be sent to reparation or be disposed from the company which will eliminate this kind of unnecessary movement (Peterson & Smith, 2001). Unclear labeling of the carriers regarding quantities, part number or location leads to contingency and longer work time. By implementing the second step in 5S, set in order, the material supply could be structured with distinct labeling. The second step of 5S, tools could be sorted to reduce searching time. After implementing these steps standardization of rules and instructions is necessary to obtain consistent labeling, and also to introduce established system for e.g. backup carriers.

6.1.4 Defected Products

If defective articles aren't discovered in an early stage it can create valueless work and quality shortages on products that lead to increased cost (Lumsden, 2012). If the defected articles are found before transferring them to assembly line it will minimize the valueless work. This can be received by implement *earlier quality controls*. Higher quantities at the PoU often cause damaged goods, and it is also space consuming. By *reducing batch size* of the carriers containing more than two days lead time at the case company, defected articles would decrease (Lumsden, 2012). That would lead to reducing the valueless work such as pick-up, transport, and leave defected articles.

The first step in *5S*, sorting, can be used to eliminate defective products from the workstation at the assembly line. Specific shelves where the operators in the assembly line could place the defected products can help material supply coordinate the route. The operator at the case company has to walk through the inventory to get the damaged goods report approved by their unit manager. With According to Minton (1998) *kaizen* can be used to increase employee involvement and empowerment by delegate working tasks and improve the flow. The handling of damaged goods could be improved using this method if an operator is performing the whole process including the damaged goods report. With an integrated cross-functional *information management system* the operators in the assembly line could inform the material supply when deficiencies have been discovered (Hong & Kim, 2002). When the material supply gets information about

damaged goods they can coordinate replacement picking with a set route. The unnecessary transportation and work due to the damaged articles can then be reduced.

6.1.5 Waiting

At the case company waiting occurs when items are blocking the operations in the plant. By using *5S* unnecessary items could be organized or removed from the workplace and aisles and thereby eliminate waiting time (Peterson & Smith, 2001). Waiting also occurs when operators are looking for right location, waiting for order or information. This can be reduced by integrating an *information management system* to accomplish easier access to information could lead to less waiting time (Hong & Kim, 2002). The system will ensure that the picking operators can choose suitable working task depending on situation in order to avoid waiting time.

6.1.6 Unused or neglected resources

By scheduling the work tasks using *standard work* the unnecessary work tasks can be reduced (Srinivasan, 2012). Instead of cleaning for two hours one day, the activity could be modified into an everyday task. Some of the cleaning tasks could be delegated to the cleaning staff to reduce neglected resources. The advantage is more motivated picking operators since the cleaning tasks are less substantial. Unused resources can be reduced by *Kaizen* which has a central focus on continuous improvement and employee involvement. By giving employees opportunity to further education such as forklift license the case company could easier redistribute the working tasks in the material supply (Minton, 1998).

7. Discussion and Conclusions

This chapter begins with a discussion of the result with emphasis on the research questions. In the methodology discussion strengths and weaknesses of the chosen approach are brought up. The final chapter presents conclusions and areas for future studies within the subject.

7.1 Result discussion

The purpose of the thesis was to improve the material supply to assembly line. To fulfill the purpose two research questions were conducted. The discussion of the result will follow these two research questions that are answered separately.

7.1.1 Non-value adding activities

The first research question was aiming to provide identification of non-value adding activities in the material supply to assembly line. The literature study gave general theories about non-value adding activities and wastes. In addition a study of a real case has been performed to contribute broader knowledge within the scope. Non-value adding activities were identified in the material supply during case study and thereafter classified into six different wastes out of eight given from the literature. The six different wastes which was identified was excess inventory, unnecessary transportation, unnecessary movements, defected products, waiting, unused and neglected resources. Since several non-value adding activities have been identified and the majority of the eight wastes have been established the first research question are considered answered.

There was limited research regarding non-value adding activities and wastes in the material supply towards assembly lines, which made the scientific research difficult. The literature study of value adding and non-value adding activities were done before the case study was performed but the authors decided to categorize the activities into the eight wastes and therefore the literature study continued afterwards. Since the literature study regarding wastes was performed after the case study the authors have observed the material supply objectively. The thesis has been focusing on non-value adding activities and waste identification, but it does not guarantee that other inefficiencies exist. Identifying non-value adding activities and wastes enables an answer to the second research question regarding reduction of non-value adding activities to improve the material supply.

7.1.2 Reduction of non-value adding activities

The second research question is aiming towards reduction of the identified non-value adding activities to improve the material supply. It was conducted by classifying the non-value adding activities into wastes and thereafter analyzing theories about improvement methods. Possible alternate improvements have been presented to the every waste that contributes to the non-value adding activities and therefore the authors

consider the second research question fulfilled. The second research question was contributed to fulfill the purpose about how to improve the efficiency of the material supply. The first research question was important as a basis for the improvement alternatives. Therefor both research questions have contributed with knowledge about a more efficient material supply process, which makes both of them connected to the purpose. Since this thesis are focusing on reduction of wastes found in the non-value adding activities, there are improvement methods that could be useful for other companies that have not been used in this thesis.

The improvement proposals that were presented have been based on established theories from both internal logistics and lean production. However, the major difficulty with gathering information from literature was to find specific information route planning and other improvement methods for internal material flow to reduce the wastes. There are many other theories that could be useful for reducing non-value adding activities, but the theoretical framework that was chosen for this thesis was the most relevant for answering the purpose.

Depending on which wastes identified in the material supply the improvements can vary. Other manufacturers could use the improvement proposals to broaden their knowledge about the material flow efficiency. The improvement methods that can be used at other companies depend on what wastes they find in their current state material supply and the priorities they make. Several improvement methods are connected to more than one waste, which leads to reduction of several wastes. The improvement proposals in this thesis are not yet implemented, the result after the implementation of the improvements can be compared with the time study performed of the current state. A summary of the efficiency improvements is presented and can be useful as foundation when improving the efficiency of the material supply:

Excess Inventory: By considering different storage policies storage space can be saved in the inventory. Reducing the batch size in PoU is another alternative for companies to be able to minimize WIP.

Unnecessary Transportation: Reduction of travel distances can be accomplished by changing storage policy. Route planning the milk-runs can lead to less number of transportations by coordinating the routes. An information management system with standard work procedures also creates a more material supply.

Unnecessary Movements: 5S will help to sort tools and eliminate broken tools such as defected carriers which will reduce the searching and walking time in the material supply.

Defected products: Discovering quality shortages in an early stage can minimize valueless work which can be done by implementing Kaizen. To reduce defected articles companies can reduce batch size at the assembly line. 5S could be used to reduce the work when handled the damaged goods to the material supply.

Waiting: By using *5S* unnecessary items could be removed or organized from the workplace and aisles. Also easier access to information would lead to less time wasted waiting.

Unused or neglected resources: Scheduling the work tasks the unnecessary work tasks can be reduced or eliminated. By using *Kaizen* continuous improvement and employee involvement could be increased.

The improvement proposals are considered to be able to achieve a more efficient material supply. By standardize and plan the activities and implement an integrated information system the variability could be reduced and thereby achieve a more efficient material handling process. Considering the improvements proposal the non-value adding activities could be reduced or eliminated.

7.2 Methodology discussion

This chapter aims towards discuss and criticize why the approach and methods were used, what was favorable with them, and what could have been improved. The discussion is regarding a single case study and literature studies where the case study was based on data collection with emphasis on observations and measurements, but also documents were analyzed. At last reliability and validity will be discussed.

7.2.1 Literature study
The literature used is mainly based on scientific articles to get a research approach and in addition course literature has been used to provide a broader perspective for the thesis. The thesis is built on several sources that have been analyzed, compared to each other which have increased the credibility of the used literature. The improvements proposal are developed on a basis of established theories and then adapted to a real case. Since the literature consists of merely published and tested theories it is considered as a reliable basis of the thesis.

7.2.2 Case study
The case study gave possibility to connect theories from the literature with a case at an established company, and that combination results in an abductive approach which broadened the perspective in the thesis. A disadvantage with an abductive approach is that the output from one method can affect the input from other methods. Since the

observations and measurements were conducted before the literature study the risk of biased results was reduced. Yin (2003) mentions that a case study performed on multiple case objects validate the result and make it more generalizable. In this thesis only one case study has been performed, however, the authors consider the result generalizable for companies with similar circumstances. The reason for focusing on one case study object is to investigate the research questions more deeply within the timeframe. The first research question was answered with data gathered from the case study and then generalized into theories.

7.2.3 Data collection
During the case study observations and measurements were the primary source of data collection. The first four observations were done during the pre-study to conceive knowledge about the area of concern. The following six observations and measurements were conducted to receive information to answer the first research question of the thesis. The first four observations the authors considered necessary because it gave an understanding about the problems in the material supply which based the methods in the later measurements. When the measure was about to be done the authors was able to perform the study with a wider knowledge. The measurements were performed during six working days in the material supply were three different operators were followed. The observations and measurements gave empirical findings that were categorized using existing theories which was important to strengthen the quantitative approach. The documentation provided by the case company complemented the observations and measurements performed and were used to create an overview of the company and material supply. Since the documentation is secondary data, the authors analyzed the data cautiously. The documentation has not been essential for the result but still necessary.

7.2.4 Data analysis
The observations and measurements were conducted before the literature study with purpose to reduce the risk of biased results. The observations and measurements gave empirical findings which was analyzed and categorized using existing theories. To strengthen the result the authors had to review the theoretical framework several times to add new or more suitable theories to give more substantial improvement proposals. By this continuous evaluation the relevance of the thesis has been ensured.

7.2.5 Reliability and Validity
The chosen approach for data collection and analysis gave answers to both research questions and thereby also the purpose. To attain high reliability six measurements with including observations were performed; two full working days for each picking operator. The data collected through literature has been supported by multiple sources to provide reliable data. Higher reliability could have been achieved if the picking

operators had not been aware of the measurements. That was not feasible because the operators in the material supply had widespread activities in the plant.

The internal validity is achieved through carefully formulated research questions to fulfill the purpose and with continuous analysis of empirical data and theories. Several meetings and discussions with the case company have increased the internal validity since the risk of misinterpretations has been reduced. The validity could have been increased if an implementation of the improvements had been done and compared with the measurements conducted during this thesis. The thesis is considered generalizable for companies with similar circumstances. To create a higher external validity several case studies could have been conducted but the authors chosen to investigate the current case company thoroughly within the timeframe.

7.3 Conclusions

To improve the efficiency of the material supply it is important to identify what causes inefficiencies. To be able to improve the efficiency of the material supply this thesis focuses on identifying and reducing the non-value adding activities. By classifying the activities into wastes the reduction of non-value adding activities became more organized and manageable. There were six wastes identified that contributed to an inefficient material supply. These wastes were thereafter analyzed and potential improvements were compiled.

There is at least one improvement proposal for every identified waste and combinations of these improvement proposals can reduce the non-value adding activities. The improvements mentioned in the thesis are change storage policy, route plan milk-runs, reduce batch size, integrate an information management system, implement standard work procedures, and continuously work with 5S and Kaizen. By implementing those improvement proposals the non-value adding activities could be reduced and thereby the efficiency of the material supply will be improved. Different non-value adding activities can be identified in cases with other circumstances which could lead to different improvement methods. Since both research questions are answered the purpose is considered fulfilled. Companies can improve their material supply by reading this thesis.

7.4 Further research

This thesis shows the possibility to improve the efficiency of the material supply. Since the study has shown possibility to improve the efficiency of the material supply by a single case study it would be interesting to see if equal result can be achieved with multiple case companies. Further research could be to implement some of the efficiency improvements and measure to compare the weight of non-value adding activities before and after. The study has also shown a need for a better integrated information system that could increase the different processes in the plant. Further investigation could thereby be investigating appropriate systems and if this kind of investment is profitable.

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Appendixes

Appendix 1. Measuring formulary

Time	Activity	Location	Observation

Appendix 2. Total percentage of activities

	Average (%)	Operator 1 (%)		Operator 2 (%)		Operator 3 (%)	
		Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Transportation	23,8	36,4	23,4	18,8	30,9	15,3	18,1
Delivery	7,2	3,5	11,1	2,4	2,0	13,4	10,6
Get Empty Carriers	4,8	0,4	3,9	1,2	2,3	14,1	6,8
Search	10,5	16,8	8,9	2,3	5,0	13,0	17,0
Scan	0,1	0,2	0,1	0,02	0,0	0,0	0,3
Get from storage	3,1	4,2	7,3	0,9	0,0	3,6	2,6
Clean	9,4	14,4	15,4	0,0	16,7	0,0	9,9
Store	0,2	1,0	0,0	0,0	0,0	0,0	0,0
Rearranging	0,6	0,5	2,0	0,0	0,0	0,2	1,0
Pick up return	0,1	0,0	0,2	0,0	0,3	0,0	0,2
Leave return	0,1	0,0	0,5	0,0	0,1	0,0	0,1
Computer	12,7	0,0	0,0	26,2	22,9	15,4	11,7
Fix labels	6,3	0,0	0,0	37,6	0,0	0,0	0,3
Meeting	1,2	0,0	0,0	3,2	0,0	0,0	3,8
Leave empty carriers	1,5	0,0	0,0	0,0	0,0	9,2	0,0
Mark carriers	0,6	0,0	0,0	0,0	0,0	2,6	1,2
Picking	10,9	9,2	18,1	6,0	7,0	10,4	14,8
Kitting	1,9	9,3	2,2	0,0	0,0	2,6	1,2
Talk	2,2	0,3	7,1	0,8	1,0	2,6	1,1
Waiting	2,8	3,8	0,0	0,4	11,8	0,2	0,5

Appendix 3. Value adding and non-value adding activities

	Average	Operator 1		Operator 2		Operator 3	
		Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
VA	12	17	20	6	7	10	15
NVA	88	83	81	94	93	90	85