Analysing the impact of size, complexity and cut-off time on waste time for outbound processes in a 3PL company

Designing a calculation tool to support labour scheduling

Master of Science Thesis in the Master Program Supply Chain Management

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Abstract

An outcome of increased competition among businesses operating within logistic services is a trend towards allowing shorter cut-off time in order to achieve competitiveness. Reduced cut-off times result in greater fluctuations in labour demand for logistic companies. Fluctuations in demand limit the ability to operate efficient, which is essential for logistics services, as it is a low margin business. Three variables, size, complexity and cut-off time will be analysed regarding their impact on waste time, in order to increase efficiency. Findings indicated that low volume of transactions, in the number of order and order lines, correlate with increased waste time. A correlation between reduced cut-off time and increased waste time was also established. Furthermore, analysis indicated a weak correlation between increased complexity and waste time. The findings concluded that both volume and cut-off time are important factors and should be taken into consideration when designing an inventory solution. A calculation tool was developed in order to support estimating of labour demand for new customers and assessments. *Leveling* smoothens the demand and allows accurate labour schedules. This method can be used for inventory processes by merging several customers' inventory processes in order to create larger and more stable demand. A merged inventory can be established by an automated inventory solution, which is in line with the trends toward automated environments. The market's knowledge regarding automated inventory solutions is considered as being very basic which creates barriers for implementing the solution. Increased knowledge regarding the possibilities with a merged automated inventory solution will allow a future implementation.

Key words: *Warehouse operations, waste time, labour scheduling, cut-off time, automated inventory solution, merged inventory*

Preface

This thesis was conducted at Chalmers University of Technology in Göteborg, Sweden during the fall 2014 as a final part of the Master Program of Supply Chain Management. The thesis was initiated in cooperation with Schenker Logistics AB at the headquarter in Landvetter, Göteborg.

Firstly, we would like to send big thanks to out supervisor Nikolai Kolderup-Finstad, Solution Design Manager at Schenker Logistics, for all support and inspiration during the project. We would also thank Mikael Bilberg for all the help with data collection from the WMS system. The supervisors, team leaders and other personnel at the Schenker Logistics in Landvetter, Arlanda and Jönköping also deserves a lot of thanks for participation in interviews and always providing answers to all our questions.

We would also like to thank Lars Medbo, our supervisor at Chalmers for his time and all the good input during the project process.

Finally, we would like to thank all the other persons that we have meet during interviews and field studies. A special thank, we would like to give Ann-Sofie for the nice welcome you have been given us every morning.

Karin Gärdefors
Anna Jösok

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List of abbreviations

ABC – Activity-based costing

DB – Deutsche Bahn

DC – Distribution center

SLA – Schenker Logistics Arlanda

SLJ – Schenker Logistics Jönköping

SLL – Schenker Logistics Landvetter

SLOG – Schenker Logistics AB

WMS – Warehouse management system

VAS – Value adding service

3PL – Third-party logistic

1 Background

The intense global economy has resulted in an increased competitive environment (Srabotic & Ruzzier, 2012). Tough trading conditions forces companies to be more specialized and focus on their core business (Andersson & Norrman, 2002). Outsourcing makes it possible for organizations to move towards a more unique competitive advantage since effort and investments can be put into the key areas. One of the fastest growing areas of outsourcing is logistics (Srabotic & Ruzzier, 2012).

As the competitive environment does not only require a competitive price anymore, but it also includes time-based features (Lia, et al., 2014; Andersson & Norrman, 2002), the third party logistic provider (3PL) becomes essential for managing customers' requirements. A 3PL can be defined as an external provider of one or more logistic services such as; materials handling, inventory control, distribution strategy, purchasing, transport planning and information system for example (Abrahamsson & Wandel, 1998).

The ability to respond quickly to customers' request represents an essential part of a company's competitive advantages. Consequently, markers such as lead-time, which describes the interval between when a process is initiated and finished (Starbek & Grum, 2000), becomes a significant key performance indicator**.** A limitation in reducing lead-time is the time window between when an order is placed and accepted for a particular dispatch (Slater, 2002), which result in companies allowing a more narrow time window. This time window is called cut-off time and correlates to the service level (Fortna, 2014; Kolderup-Finstad, 2014). The cut-off time will in this thesis be defined as the time from the last point where the customer has to place the order to the time of where the order must be ready for delivery.

Related with the rapid development of Internet, several companies choose to adopt an Internet channel and conduct their business on the web (Bose & Pal, 2006; Enders & Jelassi, 2000). One of the reasons why the majority of companies choose to expand their business on Internet is the increased perceived value it provides the customers. It allows customers to order when they prefer and they receive a customized package shortly thereafter (Bernstein, et al., 2008). It is the delivery time that plays a major part in the logistic business, as customers define the time waiting for deliveries as waste (Sheu, et al., 2003). As mentioned above, companies respond to this with offering shorter cut-off times (Fortna, 2014; Kolderup-Finstad, 2014). The result is greater fluctuations in labour demand for logistic companies. Today, most practitioners rely on their individual judgment and experience when conducting labour scheduling (Choi, 2009). In order to achieve efficiency, companies need to have access to an assistive device with accurate data to accomplish a correct forecasting for labour (Harvey, 1998; Thompson, 1998; Gilman, 1993).

This Master Thesis will have its focus on designing a calculation tool that supports decisions regarding cost-efficient labour scheduling, and Schenker Logistics (SLOG) will be used as a case study. Schenker Logistics is a specialist in third party logistics and provides overall solutions in the global company DB Schenker (DB Schenker, 2014). Schenker Logistics has distribution centres in four cities of Sweden: Arlanda (Stockholm), Landvetter (Göteborg), Jönköping and Nässjö. The head office and one of the biggest distribution centres are located in Landvetter and this is the place where this thesis will have its focus.

Schenker Logistics provides complete logistic solutions to their customers with a custom-made design of the warehouse. The goal for SLOG is to offer a high flexibility and efficiency to be able to reduce the total logistic cost for their customers. To be able to do this, SLOG must continuously have an ongoing evaluation of the processes and the operations at the warehouse to be able to improve the service level and the cost for their customers.

2 Problem Analysis

The move towards a more time based environment requires the ability to perform services with reduced lead-time. Variation in orders and their cut-off time creates an uncertainty in demand for labour. Striving for a cost efficient labour that still is able to handle a fluctuating demand is an issue that employers, policy makers and new entrants struggle with (Harvey, 1998). The two scenarios that can occur, having a too high capacity or too low capacity, lower the performance of the company. A to high capacity reduced the profit margins while a too low capacity results in a poor customer service (Thompson, 1998). Even though the demand for a cost-efficient labour scheduling is identified, there is no tool that exists in order to help support the decision. Harvey (1988) claims that one essential factor for the absence of a functioning tool is the lack of reliable time-series which the tool should be based upon.

Frankin and Johannesson (2013) conducted an in-depth time study at Schenker Logistics. In this time study each process was measured and used as theoretical time when designing a calculation tool for the purpose of supporting cost-efficient labour scheduling. The result indicated a significant difference between the reporting hours for the operators and the measured time from the time studies. The created calculation tool showed a surcharge on the theoretical time of 30 % up to 80 % depending on size and complexity of the customers. Size and complexity were identified by Frankin and Johannesson (2013) as the two most significant variables that affect waste time. The size of a company is defined according to their amount of orders as well as the percepted work load and the complexity is rated considering complicated work tasks. Frankin and Johannesson (2013) argue that this high and unexpected result has its roots in different possible factors. To the theoretical time, an allowance on the standard time always needs to be added (Das, 1990). This factor contains time for work instructions from team leaders, brakes, social activities, physical or mental strains, minor machinery maintenance, deviations etc. In the total waste time, the waiting time for new orders to arrive is also included. This calculation tool thus not considers cut-off time as a factor of impact. The result from both an increased global competition and the usage of e-commerce as a distribution channel is a more frequent reduction of cut-off time. Therefore, it would be interesting to investigate how the cut-off time will impact the waste time.

What Frankin and Johannesson (2013) also show in their thesis is that the size and complexity has a great impact on waste time. The largest waste time will be given for smaller customers with high complexity in the process. The authors describe this as a combination of an added allowance on the standard times and the fact that a complex process has a greater non-value adding time since the operators more often have to wait for new orders to arrive. This means that the capacity of the operator is not fully used and the customer also pays for that non-productive time. A reduction of waste time will therefore be beneficial for the customer from both an economical and a service level perspective. To be able to reduce the waste time one possibility is to merge smaller customers and treat them as one larger. The customers are in this case merged in the same shared warehouse, where the shelves and racks, operators and processes are shared. The customers will therefore not have their own, customized area in the warehouse. The objective for having a standardized solution is to ease the decision regarding labour capacity and therefore also simplify the process of providing an accurate quotation to customers. Trends in the warehouse industry are going towards more automation for storage and sorting (DB Schenker, 2014) and standardized solutions would have greater possibilities to create an automatic warehouse solution. Market surveys regarding how the customer would respond to a standardized solution would provide valuable information for further developments regarding reducing the waste time by aggregating imbalances in labour demand.

3 Purpose

The purpose of this Master´s thesis is to generate a calculation tool that especially focuses on how the cut-off time, together with size and complexity, will affect the waste time.

Furthermore, the thesis will include an analysis of the possibility to merge several customers into one, as the size of a company tends to have a great impact on waste time. The aim is also to establish a deep understanding about customers' opinion and context regarding aggregating labour imbalances by creating a standardized solution and if an automatic warehouse solution will be beneficial in the standardization process. The intention is also to describe which types of clients are suitable for the combination.

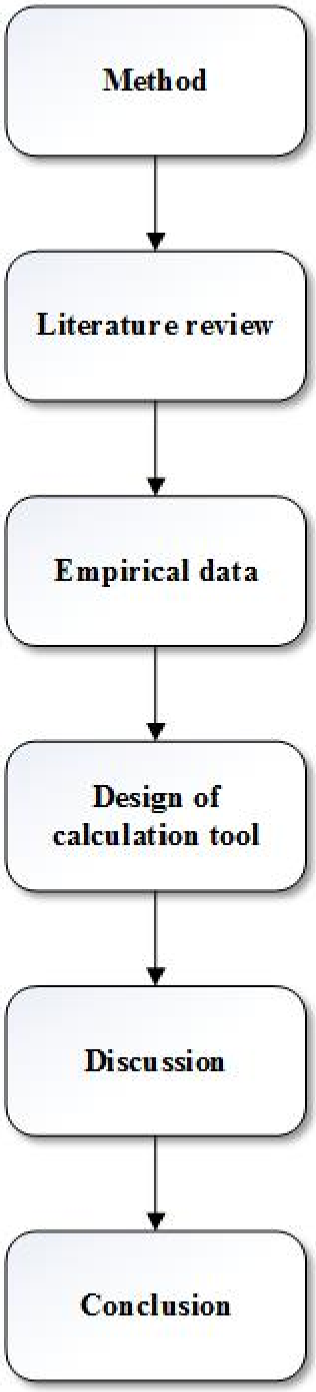
3.1 Research Questions

1. In which rate does the theoretically calculated need for labour and the actual labour demand differ?
2. In what way will combining customers affect the waste time?
3. In what context will a merge of customers be suitable?
4. Will an automatic warehouse solution be a possible solution for combining customers?

3.2 Scope

The scope of this Master Thesis will be to focus on three variables; size, complexity and cut-off time and how these will affect the waste time in a 3PL company. The usage of the calculation tool will be to simplify the process of scheduling the blue-collar labour for new and existing assessments.

4 Thesis Outline



Method – The chapter describes how the research for this study was conducted. The chapter will discuss the data collection, the development of the calculation tool and the method for market research.

Literature review – In this chapter, the theoretical background relevant for the thesis will be presented. Concepts such as warehouse management, labour scheduling and time allowances will be explained as well as overviews of companies visited in four field studies.

Empirical data – The empirical data chapter contains information about Schenker Logistics and all the companies operating in the warehouses. A general description of the outbound processes is followed by a detail description of all customers. Also, gathered data from the market research will be presented in this chapter.

Design of a calculation tool for estimating labour demand – This chapter will in detail describe the development of the calculation tool. The variables of size, complexity and cut-off time will be defined and the waste time for each customer will be calculated. Starting from the calculated values, a multivariable analysis will be performed to calculate the waste time for the remaining variable combinations. The result will be analysed and discussed. Also the results from the market research will be analysed and discussed in this chapter.

Discussion – In this chapter, the outcome of the dependency of size, cut-off time and complexity for the waste time will be discussed along with the outcome of the market survey will be discussed. Some recommendations for SLOG in the usage of the calculation tool will also be presented.

Conclusion – Finally, the study will be summarized and the conclusions will be presented along with suggestions for further research.

5 Method

This section will describe the methods that were used to be able to fulfil the purpose. It describes the research design and approach as well as the data collection and analysis.

5.1 Research Design and Approach

This thesis was designed as a case study with DB Schenker Logistics used as the studied company. The method of case study allows the study to retain a holistic view of reality and provides a variety of evidence such as observations, interviews and documents (Yin, 2009). The thesis was divided into two parts. In the first part the relations between waste time and the factors in focus: size, complexity and cut-off time were investigated. The major share of collected data was treated with a qualitative approach, as the definition of the three factors were analysed by support from interviews and discussions. Also quantitative methods were used when analysing secondary data from Schenker database. In the second part customers' opinion regarding aggregating labour imbalances by creating a standardized solution was investigated and this part of the thesis was also based on a qualitative approach with interviews as the main information source.

Furthermore, a cross-sectional design was used since the data was collected from more than one customer within Schenker Logistics (Bryman and Bell, 2011). Using a cross-sectional design endorsed comparison of processes for different customers. This comparison allows an analysis of several different variables.

A qualitative method entails few restrictions on the answers given during the interviews. Instead it emphasized on openness, which in a greater extent provide opportunities for the interviewer to receive detailed answers and obtain a deeper understanding of the chosen topic (Jacobsen, 2002). Another advantage of the thesis being based on a qualitative method is that the method is flexible. Data collection with a qualitative method often requires an interaction between authors and respondent and as the authors have chosen a relatively wide field of study for the second part of this thesis, this may create a need to change the focus on the problem description, and also the mode of data collection along the thesis.

The thesis has an inductive reasoning, as the majority of data collection is based on qualitative research and then describes theory on the basis of empirical data (Jacobsen, 2002). As a large proportion of the collected data will be gathered and processed through interviews, an interpretive, hermeneutic, is considered to be an appropriate approach (Esaiasson, 2007).

A limitation in this research design was the focus on processes only related to outbound, i.e. picking and packing processes. The inbound processes were in this way not a part of this thesis since those processes have a greater variation in appearance and were therefore harder to treat as standardized. This will give an uncertainty regarding the application of the results on a complete process containing both inbound and outbound processes.

5.2 Current Situation Analysis

To obtain a more comprehensive picture of the investigated environment, a current situation analysis was conducted. The analysis contained interviews with the manager of solution design, supervisors, team leaders and blue-collar operators regarding their current way of working. The function of the warehouse was investigated as well as the overall flow. All the current customers in the warehouse were thoroughly reviewed to get an overview of the different type of demands and seasonal variations that exists in the warehouse. The supervisors for each customer were also interviewed regarding the variables size, complexity and cut-off time. After the current situation analysis, a selection of appropriate customers for further analysis could be conducted. Not all of the customers were suitable for the analysis in this thesis according to too long cut-off time, light assembly etc.

5.3 Literature Review

A literature review was made in order to introduce relevant theories and to provide a deeper understanding of the related concepts. The literature review also provides previous research within the field. The relevant theories for the literature review were conducted from articles and books available physically and in the databases at Chalmers Library. The chosen subjects that would create a foundation for the thesis are listed as follow:

- Warehouse management
- Warehouse picking technologies
- Lean and Warehouse management
- Cut-off time
- Takt time
- Allowance
- Labour efficient scheduling
- Trends and automated warehouse solution

In addition to the literature review, four field studies were made in order to acquire a deeper understanding in how other businesses handle their warehouse operations. The field studies were performed at three non-competitive companies, all having their warehouses in-house, and one company selling automated warehouse solutions. Two of the companies used automated warehouse solutions where the third company used manual processes. The processes and the warehouse design at the companies were investigated and interviews with the hosts were performed where the questions mainly related to the flow in the warehouse and the labour scheduling process.

5.4 Data Collection

Data collection can be divided into two categories, according to Bryman and Bell (2011). The two categories handle primary data and secondary data. The primary data was gathered through interviews with employees at Schenker Logistics from relevant working areas. Furthermore, observations of the outbound processes were conducted in three warehouses. The secondary data was collected from Schenker Logistics' database.

5.4.1 Interviews and Observations

To be able to gain understanding about the processes and flows at SLOG qualitative data through interviews and observations were collected. Interviews were made with first supervisors and later team leaders and other personnel from the production. The questions for the two different interviews were prepared in advance and the same questions were asked all the supervisors respective team leaders. A semi-structured principle was used as foundation in both interviews. The semi-structured interview in general starts with a number of open-ended questions that is predetermined and the dialog continues from these questions. The interview method can be used for either individual in-depth interviews or in group discussions (DiCicco-Bloom & Crabtree, 2006).

The interviews for the supervisors comprised questions about the flow in general, size, complexity and cut-off time personnel planning while the questions for the team leaders had the focus to gain deeper insight of the flow. For these interviews a template for a general process design was filled with specific values for the given flow. Along with the gathered qualitative data, quantitative data from Schenker database was needed as additional input in the template to conduct the calculations. By filling out the same standardized template, the process of comparing the data during the analysis was easier performed. Only the flow of the outbound process was investigated according to the focus of this study. The template that was used can be found in Appendix III. Some questions in the template regarding numbers and fractions were especially hard for the interviewers to answer and that was why observations were made in addition to the interviews.

To get specific additional information for the template in Appendix III, operators were interviewed. For information regarding how many cartons that are used per route, at least two persons were interviewed but observations were also done in order to validate the answers. The information about which type of transport used during the route was also gained from interviews and observations. Which type of shelves and which levels that belongs to the specific customer were received from the interviews while the picking height, depth and weight were measured and estimated according to observations and depending on usage of ABC-classification or not. Visually, an observation also showed if the upper levels were occupied or not which also contributes to the average picking height. The same method was used for the picking depth. The average carton size was estimated through observation and to the size of the carton an arm length of 30 cm was added. The study made by Frankin and Johannesson (2013) showed that the weight factor did not have any large impact on the total time and therefore the standard weights were used, however, they could differ from the actual weight. The type of goods picked is both full pallets and single picks. A large part of the customers at SLOG has both types of goods and the orders often contain a mixture of the two goods types. To get the fraction of the two goods types, at least two operators were interviewed and observations were also used. To verify the gained numbers, data from the database was analysed. In the packing process, mainly interviews were used to get information.

Interviews were also made for the second part of the thesis where the possibility of merging smaller customers and treat them as one larger was discussed. The method for this interviews can be seen in paragraph 5.6 about Market Research.

5.4.2 Other Data

The secondary data used was provided from the database at Schenker Logistics. The database is well developed, due to the long usage of the WMS and a large amount of data found. The gathered raw data contained information of orders from 2013-09-01 to 2014-08-31. The raw data was sorted in Microsoft Excel to be able to get the number of orders, number of order lines, number of shipped packages and pallets, picking zones, picking stops and the billed working time for each customer. The collected data was used in order to calculate the waste time and develop the calculation tool.

5.5 Design of Calculation Tool

The design of the calculation tool was performed by first selecting a large amount of existing customers at SLOG. For each customer the size, cut-off time and complexity was defined in a three point scale. This was performed by analysing the collected primary data from interviews and the secondary data from the SLOG database.

When calculating the waste time for each customer the first step was to calculate the theoretical time needed for the outbound processes and this was achieved by using the calculation model developed by Frankin and Johannesson (2013). The calculation model needed both primary and secondary data as input. In the model, secondary data was used as a basis but the primary data was also needed regarding which processes the specific customer used, the number and type of storage space etc. The output data from that calculation model was given as the theoretical time, in hours, that the customer used during one year, an interval from 2013-09-01 to 2014-08-31. The theoretical time was compared to the actual time, given from the SLOG database, of which the customers have been billed. The difference between the actual time and the theoretical time gave the waste time for each customer.

Together with the definition of each customers' size, cut-off time and complexity, the waste time for the specific classification was set and a calculation tool was developed in Microsoft Excel. The program is a further development of the calculation model created by Frankin and Johannesson (2013) where now also the waste time will be given as an output. The calculation tool developed in this thesis will use the variables size, complexity and cut-off time, each one divided in a three point scale, as input and generates the percentage of waste time correlating to the specific combination of the three variables. The tool is based on the waste time of the customers at SLOG today. Since customers for all possible combinations of the three variables are not present at SLOG, the missing combinations are linearly approximated.

5.6 Market Research

Frankin & Johannesson (2013) stated that the size of the customers has a great impact on waste time and smaller customers create more waste time than large ones. In this study, this hypothesis was tested and if the hypothesis was true an investigation of the possibility to merge multiple inventories would be conducted. In this case the customers will be treat as one customer, in a so called shared warehouse, in order to create larger volumes and thereby reduce the waste time.

To gain a professional opinion, Business development managers at SLOG were interviewed to get an overview of the selling process and an overall opinion regarding the markets reactions about combining several customers in order to treat the customers as a large one. Further, 11 interviews with companies in five different branches were made. The interviews were made with companies using both in-house warehousing solutions and companies using 3PL providers. In all cases, persons responsible for the companies supply chains or warehouses were interviewed and the same questions were asked. The questions contained a general part where the current situation at the company was discussed, one part concerning the opinion of using a standardized, shared customer warehouse and the last part of future trends and automation in warehousing. The questions can be seen in Appendix II.

6 Literature Review

In this section, a frame of references will be designed and the theories used in this thesis will be presented. The theoretical background will describe prior research in the fields of, for example, warehouse management, warehouse technologies and allowance. The section also contains overviews of companies visited in four field studies where non-competitive businesses were investigated.

6.1 Warehouse Management

The production of goods has steadily increased globally. The distance between production and customers leads to longer lead times, which is the opposite of today's market demand. Along with increasing demand from customers and a growth of e-commerce, the importance of warehouses has been augmented and is now seen as a fundamental part within the supply chain.

6.1.1 Reasons for Using Warehouses

Warehousing is often seen only as a cost driver for companies, but most businesses are compelled to store their goods. A storage can be managed in-house or by a third-party logistics (Abrahamsson, 1998). Regardless of which alternative that a company chooses, the major reason for applying a warehouse is to achieve logistic optimization. When an order is placed, it is expected that the order is treated right away, allowing instant order fulfilment. To be able to provide immediate handling, it requires that the products are available. In order to make sure that the products are available, forecasting and stock keeping is essential. When production and consumption are located with a distance in between, a warehouse is able to bridge the distance and status for products. It also provides shorter lead times, since barriers for transportation such as custom clearance often can be a time consuming factor (Richards, 2011).

Initiating a strategically located warehouse would also be a competitive advantage. Allowing small and frequent orders with short lead time contributes to an improved market position. The trend towards mass-customization leads to a great variety of products. Companies that offer a wide selection will gain competitive advantage related to a high quality of customer service (Richards, 2011).

To cooperate together with a warehouse that functions as a buffer enables the remaining supply chain to have lean processes. This strategy reduces cost along the supply chain, but creates inventory costs. This dilemma differs if the warehouse is run in-house or by a 3PL. Having inventory is a part of the business idea for a 3PL. Here, the focus lies in optimizing the processes within the warehouse in order to provide competitive offers and customer service. When managing a warehouse in-house, an important part of the task is to handle the level of inventory. This requires decisions regarding obsolete products, establish accurate forecasts and analyse order patterns. A 3PL also need to analyse order patterns in order to locate the products in strategic places (Richards, 2011).

The basic idea of using a 3PL is to cut costs. Since a 3PL operates with several customers, it allows economy of scale, which often makes the usage of a 3PL the better economical choice. The cost of labour and equipment decreases with efficient utilization. By being able to consolidate goods and increase the load capacity, transportation costs will also decrease.

Outsourcing the logistics to businesses with great knowledge and skills within the area allows companies to focus on their own core business and at the same time provide better service for their own customers (Andersson & Norrman, 2002). Furthermore, a 3PL often offers additional services. In the struggle to meet the customer demand of customization, postponement of differentiation is a possible solution. By letting the final step in the assembly or similar processes be conducted in a warehouse, the result will be a lower inventory and reduced costs. Brodin and Kohn (2008) also mention the positive environmental effect of centralized distribution centres, with greater opportunities to consolidate and reduce transportation.

6.1.2 Challenges for Warehouse Management

3PL companies are facing a number of challenges in their attempt to cut cost, operate efficiently and at the same time increase the customer service. One challenge is the great seasonal variations. These variations affect both the space needed for the warehouse and the number of employees and equipment. This puts a lot of pressure on the ability to plan and schedule their operations in order to be competitive (Richards, 2011).

Another challenge concerns the fact that warehousing is a low-margin business. Handling low-value products and high-value products, low volumes and high volumes requires the same amount of labour and equipment. The picking and packing of low volumes are especially tricky to manage since the increase of e-commerce contributes to a great amount of low-volume orders (Richards, 2011).

A third challenge the 3PL companies must handle is the short lead times and on-time delivery. Next-day delivery is often considered as a matter of course (Richards, 2011). Not delivering on-time could cost the loyalty from the customer, as there are often several competitive businesses that sell the same products. This challenge touch upon the first challenge, as an excessive focus on productivity may lead to a deficient capacity which in worst case could lead to a delayed delivery. Furthermore, in order to provide high qualitative customer service, enabling the final customer to follow their goods throughout the transportation to the final destinations requires an integrated system of the warehouses systems and the customer, and this often requires an investment and collaboration (Richards, 2011).

As a sequence from the trend towards mass customization, the number or product variations have increased dramatically. The result of this is a greater need for both a larger number of picking stations, but also a more volume efficient way of storing picking goods. The increased number of order lines also entails a management of controlling which article numbers that have the high frequency, in order to display these products in strategic positions, which allow efficient picking. But since a warehouse contain order lines, which are picked less frequently, decisions regarding possible obsolete products must be made (Richards, 2011). E-commerce reflects the trend towards reduces size of the orders and increased frequency of orders. The high level options and customization in e-commerce results in a great increase of article number (Kolderup-Finstad, 2014) but also, linked to required customer service (Bendoly, et al, 2006), a reduced lead time (Fortna, 2014).

6.2 Warehouse Picking Technologies

The modern warehouses today are monitored by many IT-systems to all the time be updated with the latest information (Connolly, 2008). Using the right technology can improve the productivity, reduce the costs and improve the warehouse productivity significantly. A warehouse management system, WMS, is a system that processes real time information about accurate inventory levels and location of the goods etc. The system can also provide picking routes in order to optimize the picking of multiple orders (Richards, 2011). To the WMS, different types of picking aids are connected in order to collect the information. There are a lot of different techniques for labelling used, such as marking directly on the package, bar codes, 2D data code and RFID (radio frequency identification) (Connolly, 2008).

The order picking can be defined as the activity of gathering a prepared range of items following the customers' order (Reif & Günthner, 2009). The process is in many cases the last step before the items reach the end customer, which makes it very important to ensure the quality. A zero level of defect picks is therefore the goal and one way to minimize errors is to automate the process. This process is both costly and will contribute to less flexibility in the process. To be able to keep a high level of flexibility in product ranges and order sizes, humans are still the best picking option. By using operators, equipped with technical devices, the process can keep its flexibility and at the same time be more efficient (Reif & Günthner, 2009).

The order picking function is often the most time consuming part of all the warehouse operations, standing for 40-60 % of the total warehouse labour hours. According to this, most companies tend to focus on this part first to increase the efficiency. In this work a lot of different techniques to support the picking process can be used (Wulfraat, 2014). Conventionally, printed paper lists are used. This method is intuitive for the operator to use but laborious to handle. Hompel and Schmidt (2007), mean that the picking list method necessarily do not need to show lower quality but in general to ensure the same quality a longer time is needed.

Modern systems will work without paper and instead the mobile device used is connected to the warehouse management system, the WMS. The most commonly used devices, which are replacing the picking list, are scanners, pick-by-voice and pick-by-light (Reif & Günthner, 2009).

The handheld scanner is a well-known device in the warehouses today. A great variety of models are on the market and the most commonly used is the barcode scanner. Scanners detect the light and dark areas of the barcode and convert this into information about the item (Hompel & Schmidt, 2007). The accuracy rate for the scanner is around 99,5%. Another variance of the handheld scanner is the finger scanner. In the finger scanner the computer is attached to the wrist and the code reading sensor attached at the finger. This provides the operators using both hands in the picking process, unlike when handheld scanners are used and the operator need to grab the scanner with one hand in order to scan the item. By being able to use both hands, the productivity can be increased. The finger scanner has the same accuracy level as the handheld scanner (Richards, 2011).

From the pick-by-voice system the operator wears a headset and gets vocal instructions of where to find the item and in which quantity the item should be picked. By wearing a headset the operator has both hands free to use in the picking process. To confirm the pick, the system asks for a control symbol (often a number or a letter) which the operator needs to recall to the system (Reif & Günthner, 2009). When used correctly, the pick-by-voice system is very polite and has an accuracy in the interval as high as 99.7-99.97% (Wulfraat, 2014). Since the system is voice activated, the environment cannot be too noisy. The question is also whether the operator can handle a monotone voice for a whole working day.

In the pick-by-light system, lights are installed in each of the slots and the picking is initiated by the lit light that shows from where the item should be picked (Reif & Günthner, 2009). Also in this system both hands are available for the operator since lights will guide the picking. The method is most frequently used in storage systems with shelf or flow racks. This system has an accuracy of 99.7-99.97 % (Wulfraat, 2014).

6.3 Lean and Warehouse Management

Along with increased competition within businesses, the warehouses all the time need to improve and streamline the process in order to get more efficient. In the manufacturing industry, the lean concept has proven to turn out successfully but the techniques might be more difficult to apply on warehouse operations. Despite this, the concept can make significant improvements in material flow and eliminating waste also in warehouse operations (Garcia, 2004).

The key of the lean concept is to improve the flow in the warehouse by reducing the non-value added tasks. Value added tasks are processes that contribute to create customer value for a product or service (Alonso & Northcote, 2013; Katz & Boland 2000). Non-value added tasks are therefore the opposite, they do not add any customer value to the product but can nevertheless exist. In a warehouse, non-value adding tasks are for example the transportation in the warehouse and waste time for operators which are correlated with the allowance described in section 5.4.

In warehouses, it is not uncommon that half of the activities performed do not add any value or lead to increased customer satisfaction while they still consume resources. The 3PL company often charge their customers for the space that is used and also the number of "touches" that are placed on each item. The touches include both value added- and non-value added activities, such as picking, packing, labelling and kitting for example. Independent of the fact whether the activity adds value or not, the customer still needs to pay for it and therefore it is in the nature to reduce the waste time for the non-value added activities (Goldsby & Martichenko, 2005).

Waste time is often driven by a defective design of processes, which results in longer lead times. According to the concept of lean, the non-value adding processes can be summarized by seven wastes that need to be reduced in order to streamline the process. Eaton (2013) states the wastes are:

- Waiting
- Over processing
- Rework
- Unnecessary motion
- Unnecessary transport
- Processing
- Inventory

The waste of waiting contains the time used to wait for material, information, people or other things to arrive. The category of over-processing includes doing more activities than are needed in the process. This will contribute to longer time spent on the process, which will increase the cost for it. Reworking means that the work needs to be re-done since it was not correctly executed the first time. Unnecessary motion stands for the human movement in the process and unnecessary transport stands for the movement of material, equipment and information. The processing category represents the activities that are not explicitly required. This can, for example, be producing unnecessary reports or unwarranted testing. The category of inventory contains cost of holding larger material inventory than needed, but also other unnecessary activities of queuing. Examples of this can be a bunch of invoices that need to be confirmed or summoned people waiting for an appointment (Eaton, 2013).

Beside the internal factors that affect the waste time, several other external factors also contribute to the amount of non-value added time. These factors can be seen as inevitable in order to be able to maintain a high service level and customer satisfaction.

6.3.1 Cut-off Time

The ability to respond quickly to customers' requests represents an essential part of the company's competitive advantages and one way to compete is to offer a short, precise lead-time. The lead-time, which describes the interval between when a process is initiated and finished (Starbek & Grum, 2000), becomes a significant key performance indicator in this case. The process for larger warehouses are often initiated when the order is send from the customer and received in the warehouse management system, WMS. The operator in the warehouse will then have a limited time to fulfil the requested order. A constraint in cutting lead-time for the customer is that the time window, between when an order is received and delivered from the warehouse for a particular dispatch, will be shorter (Slater, 2002). This time window is called cut-off time (Fortna, 2014; Slater, 2002). Not surprisingly, the cut-off time correlates to the customer service, provided that the delivery precision still is held. The increase in customer's service is correlated to the fact that a shorter lead-time reduces the time limitation for the customers (Kolderup-Finstad, 2014).

Today the stores do not have any particular inventory in the shops. Instead, a continuous flow of products will be delivered from the central warehouse. When a product is sold, a replenishment order for this product is created. The replenishment order is conducted as the store want to refill the product as fast as possible to be able to sell it again. To be able to achieve a fast replenishment, shorter lead-times are needed. In order to reduce the lead-time time, allowing shorter cut-off time is one solution. This reduces the time between receipts and delivery of the order (Scott et al, 2011).

Related with the rapid development of Internet, several companies choose to adopt an Internet channel and conduct their business on the web (Bose & Pal, 2006; Enders & Jelassi, 2000). One of the reasons why the majority of companies choose to expand their business on Internet is the increased perceived value it provides the customers. It allows customers to order when they prefer and they receive a customized package shortly thereafter (Bernstein, et al., 2008). It is the delivery time that plays a major part in the logistic business, as customers define the time waiting for deliveries as waste (Sheu, et al., 2003). As mentioned above, companies respond to this with offering shorter cut-off times (Fortna, 2014; Kolderup-Finstad, 2014). A delivery time of 24 hours from ordering the products to receiving them is not uncommon today (Kolderup-Finstad, 2014). The result of shorter cut-off time is greater fluctuations in labour demand for the logistic companies.

6.3.2 Takt Time

Takt time is mostly adapted by production systems. But the essence of takt time and lean production is the ability to adjust the processes according to customers demand, change of volume and new products and processes (Bertoncelj and Kavcic, 2012). This philosophy can be adapted within all processes that handle material, in order to achieve efficiency. The philosophy of lean focuses on what the demand is, in which volumes and when it is needed, with maximum utilized resources. This requires high flexibility and elimination of all kinds of waste during the processes. Takt time initiates the rhythm or the interval of time for a process. The takt time is often adjusted to customer demand, in order to be able to meet the demand but avoid over producing. Takt time is usually applied for the operation in a process, which is considered as the bottleneck for achieving a smooth flow between the processes (Centaur Communications Ltd, 2004). When calculating the required takt time the requested output must be known, as well as the available working time for the period of the demand. For warehouses when the demand is unknown and has great fluctuations, since orders can be received during the whole day, it becomes difficult to dimension the capacity according to demand.

6.4 Allowance

The standard time is an engineered time of how long time an activity will need to be performed by an experienced operator, based on established methods and working conditions of the activity. The higher quality this data has, the easier it is to simulate the actual time needed for an operation. This time standards will be applied in many areas, for example labour scheduling, equipment justification and team sizing (Zandin, 1994).

During a full day of work, the entire period is not spent on the actual work. Zandin (2001) explains that this non-productive time includes, for example, visiting the restroom, talking to supervisors and other workers (both work related and non-work related), waiting and getting instructions etc. These factors will never reach a zero value but the goal is to minimize them. Some of these factors are in some way related to the work and detecting them is the first step in streamlining the processes. Other factors that are non-work related will be desirable to remove to the greatest extent possible to reduce inefficiency.

The time that is needed for the non-working periods are often referred to as allowance, which can be divided into categories of example personal needs, fatigue, delay and contingency. To compensate for this factor, a percentage of the standard time is usually added (Wild, 1995; Zandin, 2001).

The allowance of personal needs contain, for example visiting the restroom and drinking water. The factor is typically set as an addition of 5 percent to the standard times (Zandin, 2001). The fatigue factor concerns the rest needed to be able to recover from the effort, both physiological and psychological, the work require, for example noise level, heat or cold etc. (Wild, 1995; Zandin, 2001). Traditionally, an addition of 5 percent to standard time is added but depending on the working task the additional factor can be as high as 50-60 percent for very heavy tasks (Zandin, 2001). The factor of delays contains interruptions throughout the work cycle. The factor relates to for example waiting for material, receiving instructions and talking to co-workers and this factor contributes with 1-5 percent addition to the standard times (Zandin, 2001). The contingency factor refers to the allowance that needs to compensate for the time needed to achieve the additional activities that are not included in the standard time since the occurrence is infrequent. When summarizing the total allowance, the factor that needs to be added is between 15 and 20 percent. However, this factor can differ a lot depending on type of process and since the percentage should be based on previous experience the exact number need to be discussed before it is used (Wild, 1995; Zandin, 2001).

6.5 Labour Efficient Scheduling

Striving for a cost efficient labour that still is able to handle a fluctuating demand is an issue that employers, policy makers and new entrants struggle with (Harvey, 1998). The two scenarios that can occur are having a too high or a too low capacity and both of them lower the performance of the company. A too high capacity reduces the profit margins while a too low capacity results in a poor customer service (Thompson, 1998). Even though the demand for a cost-efficient labour scheduling is identified, there is no tool that exists in order to help support the decision. Harvey (1998) claims that one essential factor for the absence of a functioning tool is the lack of reliable time-series, which the tool should be based upon.

A method for facilitating an accurate labour scheduling is leveling, which is associated with production smoothening. Leveling advocates a stable flow and production smoothing. This could be achieved by stabilizing the flow by producing the average demand over time instead of producing just-in-time with an uneven demand. The concept of leveling contributes to a predictable and even demand. Leveling allows accurate work schedules, which also result in over time savings. For inventory processes, this method could be compared with merging several customers’ inventory processes in order to create a larger and more stable demand. In order to achieve an efficient use for leveling, the method requires a high level of planning (Reyner & Flemming, 2004).

6.6 Trends and Automated Warehouse Solutions

Traditionally, warehouses use humans in the majority of their processes and especially in the order picking process. The order picking process is a process that follows the customer's need. A specific order has a specific request, which correlates, to a specific location in the warehouse, where the operator will be allocated (Hamburg & Verriet, 2012). The trend for the markets demand moves towards a more customized need. Along with businesses reducing their inventory at their stores in order to establish a pull system, this results in small and frequent orders to the warehouse. As mentioned earlier, the cut-off time is an essential factor for competition, which also contributes to a limitation of scheduling efficient picking processes (Richards, 2011).

When it comes to human operators, the productivity is low, related to automated solutions, as an operator's work comprises learning, injuries, wages and human error (Sowinski, 2013). Since the cost of operator's in the picking process stands for more than half of the operational warehouse cost the process is also designed around the human operators (Wulfraat, 2010). Several methods for the picking process has been developed in this area in order achieve a more cost efficient picking process. A collection of these are methods such as combining batching with zoning, single-order picking with zoning, only single order picking, batching and sort-after pack.

The high cost for manual picking processes is a trigger to think in new ways and the trend tend to be automation of the warehouse (Hamberg & Verriet, 2012). This is also demonstrated by a study from SLOG (2013), which indicates that the future trend for inventory processes incline to development towards automated inventory solutions. This goes also in line with the fact that logistic services have low margins. An automated solution allow the logistic process to decrease the number of operators involved in the process, which would result in a less cost intense and more efficient process (Sowinski, 2013). In addition to a more cost efficient inventory process with automation, a higher accuracy will also be achieved (Apprictity, 2013). A higher quality of the inventory processes is an additional incentive for companies using automation, since quality correlates with customer service. An automated inventory solution can have different levels of automation. The picking process can be fully automated, but can also be supported by automation and still be conducted by operators. An automated solution will have to be adapted according to the characteristics of the goods. The characteristics of the goods are for example the way there are stored, which could be full pallet, cartons or single items. The automation can handle the placement into storage, transporting the goods to the different areas in the warehouse, and sort packages and pallets according to their final destination (Sparf, 2014).

6.7 Field Studies

To be able to get a broader view of warehousing, other business were investigated. Of the four companies that were visited, three of them are non-competitive and they all have the strategy of keeping the warehouse in the organization, i.e. the warehouse is kept in-house. The forth company visited is a company providing automated warehouse solutions.

6.7.1 Volvo Cars

The material flow at the one of the warehouses at Sweden's largest car assembly plant, located in Torslanda, was visited in one of the field studies. The warehouse feeds the final assembly line with various components, mainly windows and interiors. The guided tour was held by the plant logistic engineers Lars Ericksson, Kristian Larsson and Linda Davidson. They also answered questions during a semi-structured interview.

The storing is kept in shelves with picking positions at the lowest level and buffer space above. The units are exchanged by a Kanban system. This means that when the ordering point is reached, the operator pushes a button which gives an indication to the forklift driver to change the bin.

The workers at this warehouse are divided into three different teams. The takt time of the assembly line initiates the productivity in the warehouse. The teams divide the workload and every team gets a fair share. Each team consists of 8 people and has the responsibility of about 20 different stations. If the workload gets unbalanced, people change team temporary.

The workers have to position themselves to an empty station, no system tells them where to go. At the station they connect to the pick-by-voice system to initiate the picking process. The order is packed in specially designed racks and when this is full the forklift driver transports it to the assembly line. Some shelves are designed as narrow aisles and the principal of “walk by” is in this case used. The picking route starts at one side of the shelve and ends up at the other one. This makes the time consuming walking process shorter. Stations that earlier showed low quality in picking, now uses a combination of hand scanner and pick-by-voice. Some stations also use a combination of hand scanner and pick-by-light. By implementing the pick-by-voice system the quality has improved significantly. Before the implementation, the numbers of faults or defect orders were about 500 ppm and today the number is 35 ppm. The goal is 30 ppm which is one order of magnitude higher than six sigma.

The takt time changes about once a year while the mixture in car models varies more frequently. These are contributing factors to the size of the orders. Articles that are ordered frequently are placed in conjunction with the assembly line in a so called broken sequence. In this way the workers at the warehouse have the ability to focus on the order picking. Also the complexity of the orders and stations vary. Some articles are very sensitive and need special handling, such as glass. Other articles are very heavy and those stations need more than one person to be able to handle the goods. The cut off time is low, with a maximum of four hours.

The warehouse focuses more on quality than productivity, but they also have a minimum of 80% for the productivity. The main part of the staff is employed by the company and only a small part is employed by manning. If the productivity would go below 80% the staff needs to be rearranged. Only the manning staff will in this case be dismissed and the permanent workers will be rearranged to other positions within the company. Except from the productivity goals, the company have an efficiency goal to reduce the personnel with 7% every year according to efficiency improvements. To reach this goal, small improvements are all the time implemented. The “walk by” system will for example be expanded.

6.7.2 Kappahl

Kappahl is a company within the fashion industry. The warehouse in Mölndal is the only distribution center within the company and the deliveries are sent to stores in Sweden, Norway, Finland and Poland. The warehouse is almost fully automated, only a couple of processes are made manually.

The goods arrive in cartons to the warehouse with containers from the producers in Asia. The cartons are unpacked from the container manually and put on a conveyor where the cartons are scanned and reception reported. The system will sort the cartons depending on content. Some cartons will go to the automatic sorting and some will go to the station for hanging garments. The garments are hanged on gallows manually and put on the over-head rail system which transports the garments through the warehouse. Every carton contains only one size of a garment and to not mix the sizes so called ties are used to separate the different sizes. The tie will give the system indication that a new size or type of garment comes next. The over-head rail system leads the hanging garments to a steam ironing process and further to the sorting process. Every store has their own outbound line which makes it a total of about 500 lines. To these are the garment transported and sorted automatically and then manually wrapped in plastic into 27 cm wide bundles. The bundles are then packed hanging in the containers and shipped to the stores.

For the non-hanging garments, the cartons are transported via a conveyer to the automatic sorting station. The cartons are opened manually and the items are put on a conveyer that leads to a scanning station. The scanning is done manually and afterwards the items are sent out, one by one, to the sorting band. The warehouse has 8 parallel scanning stations which can handle up to 12 000 pieces per hour. The sorting band goes around a slot- and box system and drops off the items in the right slot. The slots are controlled by the volume of the standardized packing boxes and when full volume is reached, the slot indicates by light to be discharged. The planning process in this station is of great importance, this in order to be able to send out a mixture of small and bulky items to make it possible for the staff to discharge the slots frequently and in this way avoid bottlenecks. The discharge processes is done manually by scanning the label on box, scanning the label on the slot and then pack all items into the box. The box is then shut and put on a transport conveyer which leads to the station for outgoing goods. At this station, the boxes are labelled, strapped and stacked on pallets. When the stacks reach a height of 6 boxes, the robots starts the out-loading process. When the goods are delivered to the stores the boxes will be returned to the warehouse.

Sensitive items, such as makeup, accessories and bags, are picked manually with hand scanner and packed direct into the standardized boxes.

The lead-time from the inbound process to the delivery of the goods is 2,7 days. Some garments, mostly basic assortment, that arrive in larger quantities are stored in shelves for a longer time period.

The E-commerce has in recent years grown significant and sells today about the same volumes as the bestselling physical store. The separated storage space at the mezzanine has therefore expanded. The E-commerce is in the system treated as one store and the orders are picked and packed as earlier described above, but instead of sending the boxes and the wrapped hanging garment they are transported to the mezzanine. Here, they have to be received and sorted into the storage bins. This process is very time consuming and each box can take up to one hour to unpack. The garments are picked by list, but hand scanners will soon be implemented. The cut off time for the E-commerce is about 5 hour.

The quality and the productivity of the processes do not have any specific goal figures. Quick quality checks are made in every manual process and random samples are also collected. The quality has a level of 99,7 %. Since the containers are transported from Asia by sea, the transportation lead time is relatively long. This makes it possible to plan the productivity for the warehouse processes. The productivity can be increased or decreased by changing number of used scanning stations for the sorting process or expand the shifts. The majority of the staff is employed by Kappahl and a smaller part is employed by manning. In case of decreased production rate, the personnel are rearrange within the warehouse and only the manning staff will be reduced.

6.7.3 Lindex

Lindex is a company within the fashion industry and have their central warehouse in Partille. The orders have a 48 hour cut-off time, and the central warehouse distributes goods to Sweden, Finland and Norway. Lindex has inventory solution designed by Swisslog and is in a great extent fully automated.

When the goods arrive to the warehouse, they are unpacked manually on to a conveyer belt. Depending on the goods characteristics and demand they have to alternative processes to undergo. If the goods are news and contains a full size range they will go directly to a cross docking. The packages are not repacked, instead sorted on a pallet and transferred to the outbound area.

The second alternative is for the cartons to be transferred on a conveyer belt to a sorting station. The sorting station is constructed by several compartments along the conveyer belt. The cartons are manually opened and emptied in the compartments, by a pick-by-light system. Under the sorting station, there is a conveyer belt with a large number of plastic totes. The totes are either grey, which represents articles considered as news and will go directly to store, or red which represents articles for replenishment. One tote represents one store. When a compartment is filled with an article that a specific store has a demand of, the tote is transferred to the end of the compartment. A pick by light systems is used here as well, and a display with information regarding the order quantity for each tote is installed at each compartment. The operator picks the right amount of articles into the tote, and when the operator consider the tote full, it is transferred to a storage or directly to the outbound area. If the tote contains articles that are considered as news, the tote is transferred to the outbound area. In the outbound area the totes are sorted on pallets by a robot, according to their final destination.

If the tote contains articles for future replenishment in stores they are transferred to a storage. The storage is handled by an automatic crane that places the totes in the shelves. When a store needs replenishment, the crane transfers the tote in a flow rack. The picking process in the refill process is done manually by operators. The operators use a trolley and a scanner, and walks along an aisle with the flow racks that are handled by the automatic crane. When these totes are full, the operator places them into a gateway conveyer belt. The totes are then transferred to the outbound area and handled with the same procedure as the other totes, sorted on pallets by a robot.

6.7.4 Swisslog

Swisslog is a company that designs and sells automated warehouse solutions, and is specialized on industries such as fashion and retail, e-commerce and refrigerated products. In order to sell their solutions Swisslog often contact companies within their niche. The majority of business is conducted with companies that have in-house inventory solutions. This is mainly because if the large investment that an automated solutions requires, and this is not in line with the short contract periods for 3PL.

The solution design is initiated by a process where Swisslog endeavours to understand the customers' processes and actual needs. The entire supply chain is considered when designed the inventory solution, to be able to maximize the savings. It is also in this process where the customer understands in detail what can be achieved and delivered. Swisslog analyses, among other things, the frequency curves of orders and optimizes the volume of the inventory in order to handle the demands. Each customer has their specific requirements of handling their goods, and therefore the solutions are always customized. Since not all products are suitable for an automated inventory solution, those products will be excluded in the automated handling and managed manually in a parallel process.

As an automated inventory solution requires a large investment, Swisslog considers a secure solution to be of great importance. A secure solution contains proven techniques and an aftermarket package of support and maintenance of the system. The quality of the automated inventory solution is considered very high, as the human element is to a large extent excluded.

7 Empirical Data

In this paragraph a company description of Schenker Logistics and the warehouses in Sweden will be presented. Further, a detailed description of the picking and packing processes will be presented. This is followed by descriptions of all the different customers that operate at Schenker Logistics in Sweden. The descriptions contain information about the process design for each customer along with a short description of the customer itself and other information needed for further analysis.

7.1 Current Situation Analysis

A current situation analysis was conducted in order to o obtain a more overall view of the investigated environment. This section describes DB Schenker Logistics business idea and three of DB Schenker Logistics warehouse sites.

7.1.1 Company Description - DB Schenker Logistics

DB Schenker Logistics, SLOG, is the 3PL provider in the group of the global company DB Schenker. The group has 95 000 employees around the world and is present in 130 countries. In Sweden the organization has 3 800 employees and a turnover of 12 billion SEK (Schenker, 2014).

SLOG mainly focuses on operations within warehousing but can also offer logistic solutions and transport services. The company has about 600 employees in Sweden and is one of the largest 3PL providers in the country. SLOG offers each customer a unique designed logistic solution depending on the customers' demand. SLOG has its warehouses located at three sites in Sweden; Göteborg, Stockholm and Jönköping. A centre of gravity analysis or the demand from the customer decides which of the warehouses that is the most appropriate of the customer (Kolderup-Finstad, 2014).

7.1.1.1 DB Schenker Logistics Landvetter, SLL

Schenker Logistics Landvetter, SLL, is a newly built DC outside Göteborg. The capacity of the warehouse is 40 000 m2 and an additional 8 000m2 at the mezzanine. The ceiling has a height of 11,7 m. The warehouse is designed with 48 gates, located at the same side of the building to be able to increase the flexibility between inbound and outbound processes. 12 customers are present at SLL and the main part is in the retail industry (Kolderup-Finstad, 2014).

7.1.1.2 DB Schenker Logistics Arlanda, SLA

In Arlanda, outside Stockholm, DB Schenker Logistics has two newly built warehouses. DC1 has a capacity of 27 000 m2 and 4 860 m2 additional capacity at the mezzanine. The height of the ceiling is 11,7 m. In the adjacent to DC1 is the regional office and about 300 m from there will DC2 be found. In total the DC's in Arlanda has 20 customers in fields of technology, service logistics, retailing and grocery retailing. SLA also has customers that demand high safety storage, such as drugs and electronics, and the warehouse therefore has specific zones for this type of goods. Only the operators who work in the zone are permitted to enter and they need to undergo a background check before they get access to the area (Kolderup-Finstad, 2014).

7.1.1.3 DB Schenker Logistics Jönköping, SLJ

DB Schenker Logistics has all together three warehouses in Jönköping, two in the Torsvik industry area and one in Ljungarum outside Jönköping. DC1 has a capacity of 13 300 m2 and a ceiling height of 7 m, while DC2 has a capacity of 9 550 m2, a mezzanine of 500 m2 and a ceiling height of 9 m. In Torsvik the ceiling height is 11,7 m and the capacity is 17 300 m2 at ground level and 3 700 m2 at the mezzanine. The customers in Jönköping/Torsvik are large by the volume and sell bulky goods, such as tire, lubricants and oils and animal feed. The flows and processes at these warehouses are relatively uncomplicated and straightforward compared with the flows and processes at the other warehouses in the company (Kolderup-Finstad, 2014).

7.2 Processes

The processes in a warehouse can be divided into inbound and outbound processes, as seen in figure 1. The inbound processes primarily consist of receiving the goods, transport and placing them in designated locations, whereas the outbound process includes picking and packing the items. In this study the main focus has been on the outbound processes, which will be described in the sections below. The outbound processes differ between the various companies. A generic process for the different steps in the outbound processes will therefore be defined. More detailed descriptions for each companies outbound processes will be described in section 7.3**.**

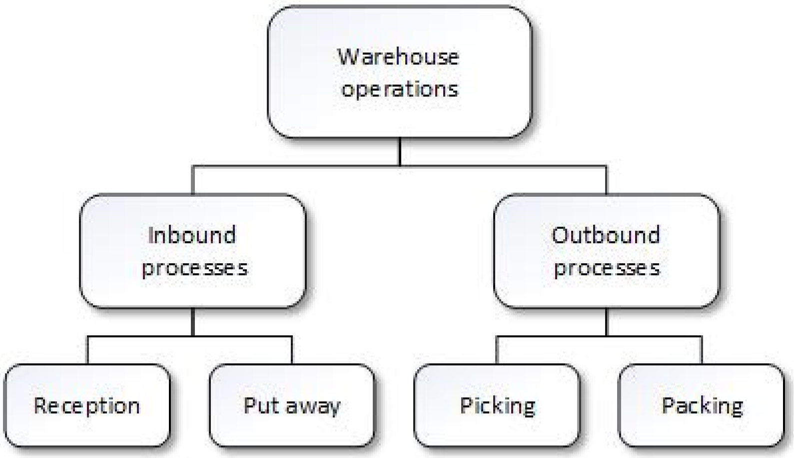


Figure 1. The figure shows an over of the warehouse operations and how they connect to each other.

7.2.1 Picking

This section describes the picking and the process contains several different steps before the packing process can start. In this study following steps are defined and described below.

1. Initiate picking route
2. Prepare picking vehicle
3. Transport during picking route
4. Vertical positioning to item location
5. Order line/Number of stops
6. Picking full pallet
7. Pick item
8. Position item to the packing area

7.2.1.1 Initiate Picking Route

The picking process is initiated by either printing a picking list, printing totes labels or printing delivery labels. Delivery labels are small tags which are printed at the same A4 sized paper with paste on its back. The labels are pasted on the cartons for which are used for packing. These are cartons that do not need to be repacked later. The tote labels are very similar to the delivery labels, except that they are used in processes when the goods firstly are picked in totes (i.e. plastic boxes for the picking process) and then repacked into their delivery cartons. The last initiation alternative is to print delivery labels. This alternative is used when full pallets should be picked. The standard time does not differ significantly depending on either of the three different initiation alternatives or depending on the size, cut-off time and complexity at the company.

7.2.1.2 Prepare Picking Vehicle

After the picking is initiated, the vehicle that will be used during the picking route needs to be prepared. The time for this procedure varies depending on which of three types of packages that will be used. The alternative of routes with cartons concerns the procedure of getting the picking vehicle, fold cartons to which the items will be packed and put them on the vehicle. In each route three to nine cartons are used and the size of these varies depending on customer and type of order. All cartons can either belong to the same order or to different ones, e.g. multipicking. In routes where totes are used, the operator needs to position herself/himself to the storage area of the totes and place the boxes on the used vehicle. In general 10 boxes are used at the same time and this is the maximum that fits at the vehicle. The last option concerns routes where the items are placed directly on pallets or trolleys without any cartons or totes that need to be prepared. In this operation a pallet need to be collected and placed on the vehicle or a free trolley.

7.2.1.3 Transport During Picking Route

The type of vehicle used during the route and the length of the route contribute to the total time of the procedure. At SLOG nine different types of vehicles are used. Eight of them are different types of forklifts and some routes are walked with a trolley. Depending on which type of vehicle that is used, the standard time varies.

7.2.1.4 Vertical Positioning to Item Location

The vertical positioning time depends on the type of vehicle and the height of the average storage location. How many times this procedure has to be done depends on the number of order lines, which is the initiator for the stops. The time associated to the activity of order lines/ number of stops involves all procedures that are connected to the positioning and the locating of the items. The activity does not consider the actual picking of the items, though this activity is seen as isolated and depending only on the picking depth and the weight of the items.

7.2.1.5 Order lines / Number of Stops

Factors that are contributing to the time spent on the numbers of stops is the combination of the type of picking method, storage solution and whether the aisles are wide or narrow. At SLOG, nine combinations of these factors were established in the production. The time studies made by Frankin and Johannesson (2013) show that picking from wide aisles are more time consuming than picking from regular aisles. This fact can be seen logical since the distances to drive/walk around will be longer and increase the times, but also the positioning time will be longer in wide aisles. In general, the time for using hand scanner as picking technique is less time consuming then using picking list. When using hand scanner, the item and the box is scanned to secure that the right item will end up in the right box. Using picking list requires more from the operator to make sure that the right item is placed in the right carton. The list needs to be check several times which is more time consuming. In addition to the already mentioned factors, significant amounts of time is also spent on opening cartons and collect empty boxes at the shelves. This time is included in all of the standard times.

7.2.1.6 Pick Item

The actual picking of the items can be performed in two different way: picking the full pallet or picking single items/cartons. The picking concerns only the actual pick; grab the item/carton and place it on the vehicle, i.e. only the depth and the weight of the items are assumed to depend on the pick. The heavier item/carton and at greater depth, the time needed for the pick will raise. Other factors that lead to the pick are treated in the previous activity for order lines/number of stops. To be able to pick a full pallet, a reach truck or a combi forklift need to be used while picking single items can be performed by any other vehicle.

7.2.1.7 Position Item to the Packing Area

The last part of the total picking process is to position the items to the packing station. This activity concerns the number of cartons or totes that will be moved from the vehicle to the packing station or how many pallets that will be put at the packing station. When all the items are placed at the station, the packing process can start.

7.2.2 Packing

This section describes the second part of the outbound process, which is the packing process. There are several alternatives for packing, and the process is individually designed for each item. The packing process can be divided into 8 different standard processes, but not every item will undergo all elements of the 8 processes since they have different preconditions to work according to. The standard packing processes are the following (Frankin & Johannesson, 2013):

1. Initiate packing
2. Enter information in the system
3. Prepare packing material
4. Pack item
5. Seal and add label
6. Put on a conveyer belt
7. Sort package on pallet
8. Load on vehicle

A more thorough description of the processes will be described below in order to understand the flow of the process, and how different items will have a different flow in the process.

7.2.2.1 Initiate Packing

The packing process is initiated when the picking process ends, which is when the operator places the picked items at the packing station. For some customers the operators will not pack their own picked goods, but another operator instead handles this. When the picking and packing process are divided between the operators, the operator who picked the items has a responsibility to make sure that the goods are easy to pack and seal, in order to avoid unnecessary work and repacking.

If the items separately need to be packed and sealed, the operator will collect the items from the position where it has been placed at the end of the picking process. If the items do not require an additional package, as a full pallet will not require, the operator can transport the items to a plastic wrapping station, or only add needed labels. Consequently, this element of the packing process will not be performed.

If a hand scanner is used during the picking process the operator does not need to control that the right amount of articles is picked, but if a list is used this additional process is performed.

7.2.2.2 Enter Information in the System

This process creates the required delivery labels and documents for the package, and this process is not dependent on previous steps in the outbound process. The operator will confirm that the order is picked and print the amount of labels needed for the order. As this process contains waiting for the printer, the majority of operators conduct tasks parallel with this activity, such as preparing packing material etc.

Information regarding which sort of transport mode the package requires is visible on the delivery labels. It is the operator’s responsibility to choose the optimal or required transport mode. The package can be treated as parcel, comfort or direct. The mode is dependent on the volume and weight of the package.

7.2.2.3 Prepare Packing Material

There are three types of packing material used in this study; cartons, plastic bags and letters. The letters and plastic bags do not require any additional time for preparation. Consequently, when items are packed in letters or plastic bags, this process will not be performed.

The process of preparing the packing material includes the activity of which the carton is gathered and folded into desired shape. The cartons are available in several different sizes and when the operator prepares large quantities of the packing material it also requires sorting the cartons into the right located for that size of carton. But for the majority of customers, the operator only prepares the packing material for the current order.

If an item will be transported in their original box this process will not be considered.

7.2.2.4 Pack Item

The packing process contains the process of which the items are moved and placed in the carton, letter or plastic bag. As several items can be handled at the same time this process is not treated as dependent of the number of articles placed in the package. This process also includes placing additional documents such as delivery notes and information, tissues and bubble plastic.

If an item will be transported in their original box this process will not be considered.

7.2.2.5 Seal and Add Label

When the final item is placed in the package the processes of sealing and labelling begin. This processes can be performed in various ways depending on the circumstances. In this study four different alternatives is possible (Frankin & Johannesson, 2013). The first one is sealing the carton with tape and adding labels. The size of the carton do not have a great impact on the time consumed on this activity, but instead the amount of tape required. As the tape roller often needs to be changed, this activity is also included in the process. The second alternative is seal the carton with plastic straps. This could be done both manually and automatically. In this study only the later alternative where used. The carton can require one or two plastic straps, and therefore the mean time is used (Frankin & Johannesson, 2013). The third alternative is for items that will be transported in their original box, and will therefore only require adding label. The last alternative is sealing with plastic bags or letters, which will be treated as the same activity as it consists of the same movement and time spent.

7.2.2.6 Put Package on Conveyor Belt

For those customers where the packing station is located with a distance from the outbound, a conveyer belt is often used. The packages can then be transported to the outbound. This activity only includes the body movement of the operator when the packages are put on the conveyer belt and any extra walking distance is excluded.

7.2.2.7 Sort Package on Pallet

When the packages are sealed and transported to the area of the outbound, the packages need to be sorted on pallets. The sortation can be done with respect to the final destination or the article number. Some customers only allow pallets that contain the same article number, this in order to ease their own handling. When sorting the packages, the size and shape is not considered to have any impact on the time required.

7.2.2.8 Load Vehicle

The final step of the outbound process is loading the vehicle. The packages and pallets are then located from the outbound and into the vehicle. The important factors that have impacts on the time consumed for this activity are how the pallets require to be packed in the vehicle. This activity is seen as a reverse unloading activity, and the average time from that process is used for this activity as well (Frankin & Johannesson, 2013).

7.3 Customer Descriptions and Processes

In the three warehouses of SLOG there are a large number of customers. The majority of customers were included in the scope of the study. However, a minority of the customers was excluded in a very early stage in the study. The main reason was that these customers had very customer-specific processes, which were not considered to contribute to a general calculation tool. The description of the included customers discloses the prerequisites for the process, such as the dedicated area of storage, type of inventory, transportations and outbound processes.

7.3.1 Customer A

Customer A is a company within the fashion industry. SLOG offers storage in Landvetter for products that will be transported to Customer A's stores as well as the e-commerce. Customer A receives orders through a joint EDI system. The latest point for the customer to place their order to allow it to dispatch the same day is 05.30 am. The orders will then be collected 15.30 am, and the cut-off time is therefore 10 hours.

For this customer, the picking process is initiated when the operator prints the picking list. The average number of orders per route is six and the operator uses a low-levelled order picker as transport during the picking route where the average picking position height is 1,35m. The aisles are wide and the goods are kept in shelves. The average transport distance for every route is 200 m. The standard average weight for a garment is 100g and the depth of the picking position is around 600mm. The person who picked the order conducts the packing process, and the average number of cartons for Customer A is 7 per order. The cartons are then sealed manually with tape and the right labels are added. The packaged is then sorted on a pallet depending on the final destination, which in this case is divided into Göteborg region and other Sweden.

In the process some extra work need to be done to control that a package of garments contain the right amount and the right sizes. The garments are often packed associated with the production in order to reduce the number of picks but in some cases it becomes the opposite, for example when the package contains two items but the store or the e-commerce customer only wants one item. For Customer A's e-commerce some orders requires an additional packing process, in which the items should be packed with tissues in order to meet the customers' expectations of a high quality product.

7.3.2 Customer B

Customer B is a company that produces products in plastic, mainly plastic bags in different sizes and designs, and uses SLL as a 3PL provider. A small part of Customer B's orders has a cut-off time of 2,5h, but as the majority of orders have a cut-off time of 24 hours the company will be considered as having only the longer cut-off time. The goods are stored in racks in wide aisles. Customer B has both a picking process of full pallets and single cartons, where 52% of the shipped packages are full pallets. The picking process is initiated by printing the delivery labels when picking full pallets and the operator use a scanner for the picking process. The vehicle used during this process is a reach truck and the storage is in wide aisles. For the remaining 48% of the shipped packages, the picking process is initiated by printing a picking list, and then an order picker is used as transport. One order at the time is picked and the average distance of the route is 260 m. The depth of picking is 600mm and the weight assumed to be 1 kg.

7.3.3 Customer C

Customer C is a retailer for wallpaper and their distribution center is located at SLOG in Landvetter. Customer C's orders are often small and released during the work shift. The cut-off time varies between eight and one hour. The picking is initiated by printing a picking list, and the orders are sorted in a U-shaped picking route. Transportation during the route is performed with trolleys that consist of up to 9 cartons, which is attached to an order picker, in average 6 orders are picked at the time. The picking route is carried out in wide aisles and can be estimated to 180 m. Products that are picked frequently are stored in lower shelves while products that are picked less frequently are placed in higher shelves. The average height position is measured to be 1,75 m and the weight of a standard wallpaper roll is 1 kg. The wallpaper rolls are packed in cartons that are prepared by the operator. The average number of moves with the items per package is assumed to be 1,5 according to observations and the cartons are then sealed with tape and address labels are added. The cartons are loaded into a grid cage and one day of orders will fill the cage that will be received by the transport company at the end of the day.

7.3.4 Customer D

Customer D is a global faucet manufacturer and their distribution centre is located at SLL. A small part of Customer D orders have a cut-off time of 3 hours, but as the major part of orders have 24 hours cut-off time the company will be considered to have the longer cut-off time. The picking process is handled with hand scanner and the operator printing delivery labels initiates the picking process. The majority of transportation during the routes is performed with an order picker, with up to six orders at the time. The picking process contains of 60 % picking in cartons and 40% full pallets. The routes are U-formed, and the average distance per route is 140m. The average depth is calculated to be 900mm, the average height position is 1,75m with an average weight of 1 kg. The packing process is in this case considered as VAS, value added services, together with other VAS processes. Since it is hard to discern the packing process from the other VAS processes the waste time only will be based on the picking process.

7.3.5 Customer E

Customer E is a company that manage printing and packing solutions, such as instruction manuals, and they have one of their distribution centre at SLL. Orders from Customer E arrive continuously during the workday, and the cut-off time can be as short as 2 hours. The operator initiates the picking by printing a picking list, which is done throughout the day. A narrow aisle truck is used as transport during the picking route in the shelves in the narrow aisles. The average route is 140 m and the average depth of picking is 700mm. Usually three to four order per route are handled during the same route, which is estimated to 140 m.

The weights of the goods vary from some grams for single papers to a couple of kilos for larger cartons. The products can be packed both in letters and in cartons, depending on the weight. If the weight exceeds 2 kilo a carton will be used. When the goods are to be transported to Mölnlycke separate packaging are required for different article numbers. For the remaining destinations various article numbers can be packed in the same carton. The cartons are sealed with plastic straps and on both cartons and letters address labels are added. The letters are sorted into plastic boxes depending on their final destination, domestic or international.

7.3.6 Customer F

Another company that has its warehouse at SLL is Customer F, a company that sells footwear and other products for the feet. Printing the picking list that is used for the picking process is initiating the picking route and two orders at the time are picked. For transport during the picking route, narrow aisle trucks are used and they are prepared with empty pallets. The picking process has both carton-picking and picking of single pair of shoes. The company store the goods in narrow aisles available at the DC and the planned route is U-shaped, which makes the picking route 180 m long. The average height for an order pick is 3,5 m, the depth is 900 mm and the average weight is 4 kg. The pallets are then automatically wrapped in plastic before the label is added and the pallet is sent.

The size of the orders varies with the season, but the fluctuations are relatively easy to forecast. The goal is to send the incoming orders the same day, i.e. 10 h cut-off time, but Customer F is not very accurate with time. They rather prefer the quality of the order.

7.3.7 Customer G

Customer G is a company that focuses on work wear and is the unbranded part of the group Customer H. Customer G has its DC located at SLL. The majority of orders have a cut-off time on 24 hours. Customer G also allows a small part of their orders to be handled as express deliveries with a cut-off time on 3,5 hours but this time is not considered in the study since the part of express delivery is rather small. Customer G uses hand scanners for their picking route. Using order pickers in wide aisles performs the transport during the picking route. Customer G stores the goods in shelves where the four lowest levels are for picking, whereas the remaining levels are for buffering. The average height position is 1,7 meters. The operators can have up to 18 smaller cartons on the order picker at the time and a large amount of orders can be handle in one route. The average amount of orders per route is estimated to be 11. When picking the items, the average depth of picking is 900mm and a standard garments weights 200gram.

The workers are responsible for packing their own picking orders. This is carried out in a separate station between the picking shelves and the outbound area. The operator starts the packing process by printing delivery labels and other documents needed. At the packing area, the documents are placed in the carton and a lid is attached to close the carton. The packed cartons are then placed on the conveyor belt where the cartons are sealed with plastic straps automatically. The cartons are then sorted on pallets depending on final destination.

7.3.8 Customer H

Customer H is a company selling branded professional work wear and their DC is located at SLL. The work wear is specially designed for each customer and delivered throughout the whole Europe. Customer H has its storage area at the mezzanine at SLL. The orders are released the day before, which gives a cut-off time of 24 hours. Additional express orders have 3 hours cut-off time, but this is a relatively small share of the total number of orders and will therefore not be considered.

The articles are stored in low, narrow shelves with seven levels. Three additional shelves are used for hanging garments, such as suits. The transportation during the picking route is a trolley. This according to that the mezzanine floor has limitations in weight load and that the aisles are narrow. To prevent too much climbing, the levels at the shelves are ABC-classified A-articles at the middle levels, B-articles at the levels above and below the middle ones and C-articles at the top and the bottom of the shelve. At the mezzanine, the picking area is divided into three different zones. The first zone stores work wear that are especially thief-prone, such as costumes for security service companies, and these shelves are therefore kept in locked cages. In the second zone a mixture of high frequent picked articles can be found and in the third zone articles that belong to one larger customer can be found. The buffer stock for Customer H is at the ground floor in narrow aisles.

The picking process starts with choosing in which zone the picking will be performed and this initiates the orders and tote labels are printed. Hand scanners are used in this process and each route does in general consist of nine totes and these are placed on the trolley. The routes are optimized by the system in U-shapes and the average route is 400m. The average picking height is 1,3 m, the average depth is 500 mm and the average weight of one article is 200 g. When the order is picked and ready, it is put on a conveyor belt and transported to the packing station.

The packing process is separated from the picking process and is not performed by the same operator. The five packing stations are designed in the same way and have the same necessary equipment. By scanning the code at the tote, information about the order is revealed at the computer. The garments are moved from the totes to cartons or plastic bags, depending on the size and the sensitivity of the order, and delivery notes and labels are printed. The cartons and the plastic bags are used to about the same extent. Every item is, in average, moved four times in the packing process and the cartons are sealed with plastic straps. When the cartons and the plastic bags are sealed and labelled, they are placed on the conveyor to be transported from the mezzanine to the ground floor. At the ground floor the packages are sorted according to the destination.

7.3.9 Customer I

Customer I is an international retailer of sports gear and is operating at SLL. Customer I is one of SLLs largest customers seen to the occupied storage area. The orders are released during early morning hours, before the work shift starts and will be picked up at the afternoon. Goods within the Göteborg area will be picked up a bit later, during the evening. This will give a cut-off time of 11 to 15 hours. As this customer handles great volume of goods, the storage area is divided into different zones according the goods characteristics.

Customer I has one zone for bulky goods where the irregular shape characterizes the goods and the difficulties connected to the handling. For orders in this zone, the operator do not use a scanner, but instead a picking list. As the orders often contain very few order lines, the operator often manages around 10 to 15 orders per picking route. As transport during the route an order picker used in an open zone. The majority of goods are placed in racks in level 1-3 so the medium high is assumed to be e meters. The bulky goods often remain in their original carton and the packing process contains of adding appropriate labels.

Another zone is items in flow rackets. These goods have also a distinct area in the distribution centre. These goods are small in volume goods, and therefore they are picked using a trolley. The trolley can contain up to 12 boxes, which corresponds to 12 different orders. The operator uses a hand scanner, which also helps the operator to make the route as efficient as possible, as it has calculated the optimal route by distance. The flow racks are placed in wide aisles and the picking is done in 5 levels which gives an average height position of 3,4 meters.

The shoes for Customer I also have a dedicated area in the storage. For this picking process a forklift is used in wide aisle and in order to avoid collisions and congestion the aisle has one-way directions. A hand scanner supports the process and the picking is carried out in 2 levels of the racks. Therefor the average height position will be 1,35 meters. The WMS system calculates the volume of the shoe cartons, and then provides a route with the maximum number of orders that will fit.

There are also zones dedicated to items already in well-formed cartons. These picking processes are conducted with a hand scanner, using an order picker in wide aisle. As the items are already in their original box the packing process is simply, only containing adding labels.

Other zones contain pallet racks with levels 1 and 2, pallet racks with level 3. The picking process for these zones is conducted in similar ways as picking shoes. A hand scanner is used, and the transportation during the route is by order pickers.

The packing is usually done by separate operators for all zones. The operator that picks the items has yet a responsibility to ensure that the items are easy to pack and seal, this in order to avoid unnecessary unpacking. The operators in the packing process also sort the package on pallets according to their destination, Sweden or Göteborg.

7.3.10 Customer J

Customer J is a worldwide retailer of chocolate and coffee and is operating in SLA. The goods consist of both full pallets, which stand for 70% of the volume, and display picking, about 30 % of the volume.

Manning personnel performs the display picking. Since the cut off time is long, about one week, it is relatively easy to plan the manning and to add or reduce staff. The display picking starts with preparation of the station. Pallets are prepared, the chocolate is picked up from the full pallets and sorted in the way that they will be picked. Also the display cartons are folded and prepared for the packing process. In the studied process the following steps are performed:

1. Pick up EU-pallets to unload finished cartons at
2. Sort out the folded display cartons
3. Open up the packages that will be packed
4. Move the single pieces from the original carton to the display cartons and place them in a given pattern according to the recipe
5. Add additional signs and parts to the carton
6. Put the outer case to the ready display carton and use tape to seal it
7. Pack the carton at the EU-pallet

The customer has a high amount of display packing, which is considered as a complex process since the type of display material varies and complicates the ability to learn the process. Since there is food that is handled, the rules from the National Food Administration need to be followed. This includes that storage directly on the ground is not permitted, the gloves need to be changed every day, the batch numbers are really important to be able to trace nuts and other allergens etc. Since the chocolate has a tendency to melt, temperature alarms are installed to be able to alarm before the temperature reaches a too high level. If that is the case, the pallets need to be lifted down from the shelves to lower levels where the temperature is cooler.

Because of the long cut off time this customer is not suitable for further investigations during this study.

7.3.11 Customer K

Customer K is a retailer for colonial products. They sell their products to grocery stores, especially to large customers in the Stockholm area and the DC is therefore placed at SLA. The orders are in general released the day before the departure day, i.e. a cut off time of 24 hours. For smaller orders at the e-commerce, a 2 hours cut off time is used.

The flow consists of both full pallets and level picking, about 50% for each category. Hand scanner initiates the full pallet picking. The level picking is initiated by picking list and a pallet is then used as foundation on which levels of goods are picked. The quantities are large enough to fill one level at the pallet and the smooth surface allows next level to be another product with other measurements, which means that no capacity at the pallet is lost.

The orders are picked from the 25 pallet racks by order pickers. The lowest level is used as picking level, while the rest of the shelves are used for buffer and full pallet picking. The average picking height for full pallet is 6 m and for level picking 1,2m with an average depth of 300 mm and average weight of 8 kg. Since a large part of the orders contains full pallets, in general, one order at the time is picked. The picking list initiates snake picking in the wide aisles and a U-shaped route to get around.

The packing process is performed by the same operator that did pick the order. Full pallets only need an attachment of delivery label while the level pallets need to be wrapped into plastic. This procedure is performed automatically.

Customer K also has a smaller part of display packing and e-commerce. The display packing is performed by manning personnel and is a small part of the total flow and is therefore not considered in this study. The e-commerce is also a smaller part of the total flow where mainly coffee machines and capsules to the machines are sold. Also, this flow is too small to be considered in this study.

7.3.12 Customer L

Customer L is a company within the gas industry that operates at SLA where they store main part of the goods at the mezzanine floor but also the ground floor is used and containers outside the warehouse building for CO_2 cartridges. The picking process has recently changed from using picking lists to using hand scanners. Since data from the current year is available, this company will be handled as they use picking lists.

In the storage area at the mezzanine, the operator manages around 3 orders per route as they walk with a trolley in narrow aisles. The picking area at the mezzanine is divided into zones of small goods and larger goods. The average distance is 270 meter and the average height position is 1,25 meters. Outside the warehouse, in separate containers, goods classified as “dangerous goods” are stored. The operators must therefore transport themselves to the containers when the goods are picked, and the average distance is 500 meters.

The operator who picked the order also packs the goods. A large part of Customer L’s good have an irregular form and will therefore be packed and wrapped in plastic. Goods that have more convenient size and form will be packed in cartons sealed with tape. When the goods are classified as dangerous, additional paperwork must be attached. First of all a label of “dangerous goods” must be attached on each package that contains dangerous goods. Furthermore, an additional “dangerous goods” label must be added if the goods are packed on a pallet and then wrapped in plastic, this in order to clarify that the pallet contains dangerous goods. Paperwork regarding what sorts of dangerous goods must be filled in and also be attached on the goods.

The majority of Customer L’s orders arrive around 48 hours before the goods are picked. A small part of Customer L’s goods can arrive 2 hours and 15 minutes before despatching. Since, the majority a goods have 48 hours cut-off time, the company will be considered to have a cut-off time on 48 hours. The company handles customers in Sweden, Norway, Finland and Denmark, and they each have around a quarter of the orders.

7.3.13 Customer M

Service logistics is a group, consisting of 9 companies, that work with spare parts and repairing goods and operates at SLA. The around 20 operators work with different companies alternately and signing their time for each company afterwards in order to provide basis for future invoices. The operators use picking lists during the picking route and the operator can take between one and six orders per route and therefore the average number of orders per route is estimated to three. During the picking process an order picker is often used, but for items with a lower position a hand held trolley with pallet is used. As the orders usually only contains one or two order lines, the average distance is estimated to 170 meters and the average position of height is four meter since the shelves are located between ground level and eight meters. The shelves are placed in very narrow aisles with an average picking depth of 600mm and an average weight per item of 100g.

The same operator that picked the order conducts the packing and the goods are packed in cartons and sealed with tape. Very rarely, the goods are packed on pallets, and if so the pallet is wrapped in plastic automatically. As the standard goods are small in volume, the goods are instead packed in cages that are a standard storage for the Swedish post. The ordinary cut-off time for these orders are less than eight hours but for a minority of the orders the cut-off time is only 1 hour. In this case, the operator books an express carrier.

According to the fact that a lot of customers are treated at the time, the processes for each customer is hard to separate which makes this multi-customer not suitable for this study.

7.3.14 Customer N

Customer N is a company selling underwear for women and who operates at SLA. The picking and packing processes are straightforward and no special handling is needed. The cut-off time for Customer N is 48 hours.

The picking process is at the moment initiated by printing a picking list. Hand scanners are, however, purchased and will be implemented in the closest future. Customer N uses three shelves in wide aisle where the first and second levels are for picking and the rest is used as buffer storage. During the picking route a trolley, with prepared cartons, is used and the route is walked in a U-shape. One route is estimated to 210 m. The average height for picking is 115 m and the average depth is 900 mm. The weight of the garments can be estimated to 100g. One order is in general picked at the time and when the picking procedure is done the same operator seals the cartons with tape.

The packed cartons are sorted on pallets, divided between Stockholm and rest of Sweden. About 40 % of the orders will be delivered in Stockholm and 60% to the other Sweden. The full pallets are manually wrapped in plastic before they are loaded on the vehicle.

7.3.15 Customer O

Customer O is a retailer selling electronics and has its DC for the e-commerce at SLA. The orders are not placed in Schenker's WMS system, the own system of Customer O is instead used. According to this, the operators use both picking list and hand scanner in the picking process. The picking list is used to support the operator with information regarding the right positon of the items whereas the hand scanner is used to interact with the system and update the inventory levels. The picking area is divided into two zones. One zone for mixed-picking, which stands for 80% of the orders and one zone for pallets, which handles the remaining 20 %. In the zone for mixed-picking the operator uses a trolley, with a maximum of 12 boxes at the time. The items are not placed according to ABC classification, but when a product is frequently picked it will be located near the packing station in the next inbound process. The average distance is 117 meters, as the operator often chooses picking lists with items located near each other. The picking depth is 600mm and the goods are stored in shelves in narrow aisles.

The second zone that handles pallets uses order pickers to pick the pallets from the racks in the wide aisles. The average height position is 4 meters and the average distance is estimated to 170 m.

For the packing process in the mixed-picking zone, 30% cartons and 70% letters are used. The parcels are, after packing, placed in a cage that is compatible with the Swedish post system. For the second zone, the packing mostly consists of manually wrapping the items in plastic as they usually remain in their original box.

Orders arrive during the whole day but if the orders arrive before 12.00am they will be picked, packed and send the same day. The cut-off time does therefore vary between 5 and 24 hours. Since the data concerning number of orders and order lines etc. is not available, the waste time cannot be calculated. Customer O is therefore not considered in the study.

7.3.16 Customer P

Customer P is a retailer of products for gardening and farming. They operate in the SLOG DC in Torsvik, outside Jönköping and they are the only customer in the DC. The warehouse delivers goods to all the stores in Sweden and also the smaller part of e-commerce is delivered from the warehouse at SLJ. Customer P has five departure windows every day and the orders are picked according to this priority. The cut-off time is about 48 hours for the retailer stores and 24 hours for the e-commerce.

The warehouse is operated by 29 blue-collar that are employed by SLOG and additionally 10 to 30 people that is employed by manning and will be used to handle fluctuations in seasonal demand. The ordinary working time is between 7am and 4pm, but when needed, offset hours are used and the working time for the second shift is then 11am to 8pm. The contract period for this customer is five years, which is relatively long compared with other customers at SLOG.

The warehouse is divided into different zones depending on the products' characteristics. The zones are:

- Dog and cat
- Combination of articles
- Handheld tools
- Clothing
- Online orders
- Campaign
- Heavy goods
- Container

The zone of dog and cat contains only sacks of different sizes and weights with animal feed and litter sand for example. This zone has 14 shelves and the sacks are picked from the first and second levels, while the upper levels are used for buffer and full pallet picking. The zone for a combination of articles is the largest one and consists of 28 shelves. The goods in this zone are all stored in cartons, which are picked to the pallets used. In the shelves, the goods are stored in descending size which contributes to a simpler packaging process since the pallets will get more even. The volume of this zone stands for 30% of the total picking at the warehouse. The handheld item zone consists of tools, unwieldy goods and chemicals and the zone has 6 shelves. The clothing zone contains clothes dedicated to farming and agriculture and the goods are stored at the second level of 10 shelves. The warehouse also has a mezzanine where the e-commerce is handled. In addition to the mentioned zones, Customer P has three smaller zones that are not very frequently used. The zone for campaign is used when certain campaigns are running. The idea is to not store the inbound goods, but instead place it at the outbound are and be picked from there directly. In the heavy goods zone, the goods need to be handled by two operators at the time during the picking process. Also a container zone exists where dangerous goods is stored at the yard in containers.

The operators operate in one of the zones and the picking route is initiated by hand scanner. Only one order at the time is handled. During the transports, reach trucks are used to pick full pallets. Order pickers are used for the picking and the vehicle is then prepared with pallets. Depending on which zone the picking will proceed in, the distance varies. Some of the zones are more time consuming than others according to the type of goods. The zone of handheld tools contains for example rakes and shovels, which also should be packed into cartons. This packing process is much more time consuming than the packing process in other zones. In the order picking process, the packed pallets are wrapped in plastic in one of the three automated plastic machines and delivery labels are added before the pallets are loaded on the vehicle. At ground floor the goods are stored in racks in wide aisles and at the mezzanine shelves in wide aisles are used. At the mezzanine floor, the picking is made by totes and trolleys. The picking is initiated by printing tote labels and 3-4 orders are picked at the time. The routes are 150 meters in average. The average picking height is 1,5 meters, the average picking depth is 400 mm and the average weight is 1 kg. After the picking process, the trolleys are transported to the packing stations. There, the items are re-packed into folded cartons. The cartons are sealed with tape, delivery labels are added and the cartons are put on a conveyer. When the conveyer is full, the cartons are sorted on pallets and lifted down to the ground floor by a forklift.

7.3.17 Customer Q

Customer Q is a distributor within specialty chemicals, selling oils and other lubricants to the industry and is operating in Ljungarum, Jönköping. Customer Q delivers their products to Norway, Finland, Denmark and Sweden. The cut-off time vary depending on destination but the average cut-off time is considered as 28 hours. The picking route is initiated by printing a picking list, where the picking list is split according to three zones. The zones are divided according to characteristics of the products:

- Cartons
- Buckets
- Oil drums

The operator picks around three orders per route and is using a reach truck. The products that will be picked are located at the first or second level of the racks in the wide aisles. The amount of full pallets is 30% and the remaining is mixed picking. As all of the products are transported in their original cartons, drums or bucket, no preparing of packaging is conducted. For the zone with the drums a claw is added to the reach truck in order to be able to handle the drums. The products have an average weight of 1 ton and are located on an average height position of 1,35 meter. Customer Q occupies 25 racks with length of 56 meters each. The average length of a route is 60 m for picking full pallets and 720 m for single picking. When conducting the packing process, the operators first sort the packages according to the final destination, which is divided into the four different countries that Customer Q delivers to. The operators then add labels and wrap the pallets in plastic manually.

Customer Q has a very small amount of dangerous goods and therefore the processes of handling dangerous goods will been excluded from waste time calculation. The complexity of Customer Q is instead affected by the need of careful handling of the goods. As mentioned above, when picking from the drum zone a claw must be added on the reach truck. This extra moment increases the picking process as the task demands high knowledge of managing the reach truck.

7.3.18 Customer R

Customer R is a company within the fashion industry and has its DC in Ljungarum, Jönköping. The DC in Ljungarum provides for stores in Poland, Germany, Finland and Sweden, but not the e-commerce. The cut-off time for Customer R is 26 hours. Customer R does not have any single picking, instead full cartons are always picked. Two different types of orders exist, referred as 018 and 019 orders. Orders that are considered as 018 orders have a greater volume and the 019 orders are more frequently picked.

The operators initiate the outbound process by printing a picking list and the final labels for each package. During the picking route for 018 orders, there are two operators that cooperate with each other, one using an order picker and one using a reach truck. The operator at the reach truck will lift down the pallet, from the racks in the wide aisles, so the operator at the order picker can reach the carton and move it to the pallet on the order picker. As there is no single item picking, every article will use their original packaging and the operators add the label directly after picking the item. The picking list is divided in to the four different countries which eases the sort process. For orders referred as 019, which have a more frequent ordering, one operator will manage the picking process. The average height position for 018 orders is 3,25 meter and for 019 orders the average is 1.30 meters. The weight is around 3 kg and the depth of picking is 600 mm.

Customer R is using their own ERP system, which does not allow the possibility to analyse their volume of orders. With respect to the lack of data from Customer R, the company will not be a part of the analysis.

7.4 Market Survey for Standard Processes in Warehouse

A market survey was designed to investigate attitudes and knowledge towards standard inventory solutions. In a standard inventory solution, multiple inventories are merged and treated as one customer. The customer's inventory is merged to the extent that they share shelves and racks and the operator is not aware of which customer he or she is operating. The operator only sees a number of orders for different customers. This method of shared warehouse can be applied on either automatic or manual inventories. In this solution the requirements of customization is severely limited in order to fit a large amount of customers. The outcome of the shared warehouse is to increase the efficacy, reduce the waste time and provide a standardized price list to the customer. This section discloses the perceptions of standard inventory solutions for different parties within the logistic industry.

7.4.1 Business Development Management and Sales Process

In order to understand how the business development managers can affect the customer's choice of inventory solution, the sales process will be described and can be seen in figure 2.

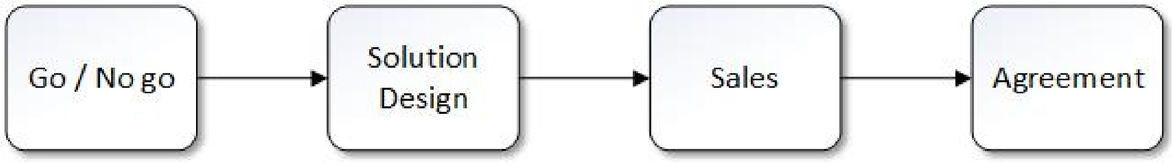


Figure 2. The figure illustrates the sales process at SLOG.

The sales process can either be initiated by SLOG contacting a customer that they have an interest in collaborating with or a customer can take direct contact. The first step in the process, the *Go or No go*, is to investigate if the possible customer is a business case or not and what is the possible winnings of the deal for SLOG. The concerns of the process involves what financial profit SLOG can get out of the deal, if it is a strategically important customer and also questions regarding liability and investments are handled. If the process receives Go, the next step is *Solution Design* where the actual process is conducted. Often two alternative solutions will be presented to the customer and further developed from the best option according to the intended customer. In the *Sales* process, the final solution will be presented but also in this step additional information and smaller changed requirements are common. If the solution and the required changes are accepted, the final step is *Agreement*. In the agreement process, the contract is signed. The contract involves a lot of information concerning, for example, contract period, a description of the sold service, e.g. the processes included, the cut-off time, the price and who is responsible for what.

In the sales process, the customer often has specified requirements of the desired outcome, such as quality, cost and cut-off time. The customer does not, however, always have a specific solution in mind, which often can be the reason for using a 3PL provider. When the customer wants to modify their current logistic solution, which could be either to invent an in-house solution or to change 3PL provider, the reason is usually a dissatisfaction of the quality, price or the relations, or the customer just what a change strategy according to the prevailing conditions of the business model. These three factors are referred, according to the business development managers, as the most important factors together with development. Quality of the logistics processes are more or less considered to be a hygiene factor. Price and the productivity is an inevitable factor because logistics is an industry with already low margins. The relationship between the 3PL and the customer is essential in order to understand each other and agree to work together toward a common goal. To be able to be competitive SLOG also refers development of logistic solutions as a factor of great importance. Development is a factor which is of great importance in the second and third step in the sale process. It is in the Solutions Design and Sale where the process is discussed and new developments can be implemented.

The standard contract period is 3 to 5 years, even though the average customer stays 8-9 years. The reason for having relatively short contract terms is that the customer wants to have the possibility to change inventory solution, change 3PL provider or go in-house.

From the perspective of the business development managers, there is no pronounced perceived competition between the customers in the sense of using a common inventory storage. In the contrary, there would be several synergies to exploit, and there is usually no need to mention what customers SLOG already does business with. The only competition that is assumed to occur would be a priority issues. In situations where the frequency of transactions is very high and the warehouse has a limited capacity, which is used by all customers in the merged standardized inventory, which customer will then be prioritized? Regarding using standard inventory solutions, where several customers are merged, there is definitely a clear understanding that the market would require a reduced price if a standard inventory solution would be used according to the reduction of possibilities in warehouse customization.

Customers are often considered to have some basic knowledge regarding automated inventory solutions, but automatic inventory solutions are usually nothing that the customer brings up as a requirement or preference.

According to two business development managers at SLOG, the market can be divided into five large branches which are as follows; electronics, fashion and retail, consumer, automotive and E-commerce. In order to get a comprehensive view of the entire market interviews were conducted for all five branches and a summary of responses follow in the coming paragraph.

7.4.2 Markets Overall Opinion on Standard Inventory Solutions

As stated above, in order to scan the entire market, interviews were conducted on businesses in each of the five business areas. When studying the markets reasons and concerns regarding current logistics solutions and also perceptions on potential barriers and possibilities with merged inventories, a comprehensive coverage for the market's needs and requirements is established. The gathered opinions of the market indicates how a future standardised inventory solution with merged inventories will encounter resistance but also enthusiasm. The collected information will support a future implementation for merged inventories as it indicates which areas that concern the market. Table 1 summarises the markets opinion. A division between business using in-house and 3PL as a current logistic solution was conducted in order to provide an additional dimension, but also to allow further analyses in how the different solutions effect the markets response to the areas in question.

Table 1. The table shows a summary of the answers from interviews made within five different business segments in order to receive markets opinion, depending on if the current warehouse solution is in-house or managed by a 3PL.

Inquiry	**Response**	
Current logistic solution	**In-house** **45 % , 5 companies**	**3PL** **55 %, 6 companies**
Reasons for choosing the current logistic solution	Associate company that manages a warehouse Ensure quality Solution adapted to business plan	Reduce prices Focus on core activities Competence History of 3PL
Benefits with current logistic solution	Using the same VMI system Full control Entire operation Ability to manage growth Customized solution	External pressure for logistic services Economies of scale Cost efficient High development of inventory solution Flexibility
Drawbacks with current logistic solution	Lack of flexibility In efficient picking process	Less opportunity to pursue development Reduced control over the processes

Most important factors in logistics	Quality Price Long term relationship	Price Quality Communication in relationship
Current duration on contract	-	6 months (1) 2 year (2) 3 year (3)
Perception for merged inventory	Must retain high priority Customization is essential	May reduce picking quality Products has specific handling requirement Economy of scale
Preferences on the other customers included in a merged inventory	Preferable not with the same season variation Not in the same segment Seclusion from other companies in order to limit the transparency of the products	Must retain a limited insight in the from other companies
Current knowledge of automated inventory solution	Basic	Basic
Existing discussions regarding a future use of automated inventory solution	No financial opportunity	Would require extended period of contract Not profitable to invest in

8 Design of a Calculation Tool for Estimating Labour Demand

In this section, the design of the calculation tool will be described. The calculation tool will be used in order to estimate the labour demand for new customers at SLOG. The variables size, cut-off time and complexity will be defined and the results of the waste time calculations will be shown. Furthermore, the waste time and the impact of the variables will be analysed. Also the results of the market survey will be analysed in this section.

8.1 Definition of Variables

In this study, three variables are used to detect the waste time in the outbound processes at SLOG. The specific variables are given by the scope of the thesis since they all have shown great impact on the waste time in the production. The variables are size, complexity and cut-off time and in the following sections the variables will be defined.

8.1.1 Size

The categorization of the variable size can be determined in several different ways. One way is to base the classification on the space and storage area used in the facility. This method is, however, not suited in this study since the storage space depends on the type of goods stored in the facility. In the case of SLOG, both the customers and the goods vary in size and therefore also the storage space needed e.g. two customers with the same number of items, but small respective large dimensions on each item need different amount of storage space. Another classification of size can be done by the financial turnover of the customers. Neither this method is suitable to use in this thesis since the value of the products in the facility differs a lot. A customer selling high margin products do not necessarily need to be of larger size than a company selling low margin products since the factor of turnover has no correlation to the volumes sold. In the case study at SLOG, the size of a customer is therefore defined as the frequency and volumes in the picking process. Data concerning the number of orders and order lines will be used together with a subjective assessment to define the variable size in this thesis.

The classification of size variable will be sorted in three different categories: small, medium and large. The categorization is not normally distributed due to the fact that the customers in the warehouse are not representing all business and industries on the market. The limits to the categories instead have the same basis used in the thesis written by Fritzson and Dietersdottir (2012) where each interval increases with a factor ten. A classification according to the number of orders will result in table 2.

Table 2. This table shows the size of the customers according to number of orders produced during one year. The classification extends from small to medium to large

Small 0 - 10 00	Medium 10 000 - 100 000	Large >100 000
Ericson&Saether	Customer K	Customer H
Customer B	Customer E	Customer I
Customer N	Customer D	Customer G
	Customer Q	
	Customer C	
	Customer L	
	Customer A	
	Customer P	

The classification according to the number of order lines will be as follow in table 3:

Table 3. This table presents the size of the customers according to the number of order lines picked during one year. The classification of the size is divided into small, medium and large.

Small 0-100 000	Medium 100 000-1 000 000	Large >1 000 000
Customer F	Customer A	Customer P
Customer B	Customer H	Customer I
Customer Q	Customer N	
Customer E	Customer G	
Customer C		
Customer D		
Customer K		
Customer L		

For the companies that fall into both the category of medium and large size, depending on number of orders or order lines, the category is rounded up. Exceptions are made for the companies that handle a large amount of full pallets, since handling large volumes is more time consuming. For the companies that fall into both small and medium size, the intervals are divided into two, which gives an indicator if the customer is in the higher or lower part of the interval. This fact will be the foundation to whether the customer will be classified as a small or a medium sized company. The flow of categorization can be seen in figure 3. A subjunctive view of the classification, together with supervisors, solution design and business developers are taken under account while classifying. Also the thesis written by Frankin and Johannesson (2013) and Fritzson and Dietersdottir (2012) indicate that a subjective assessment provides a beneficial outcome.

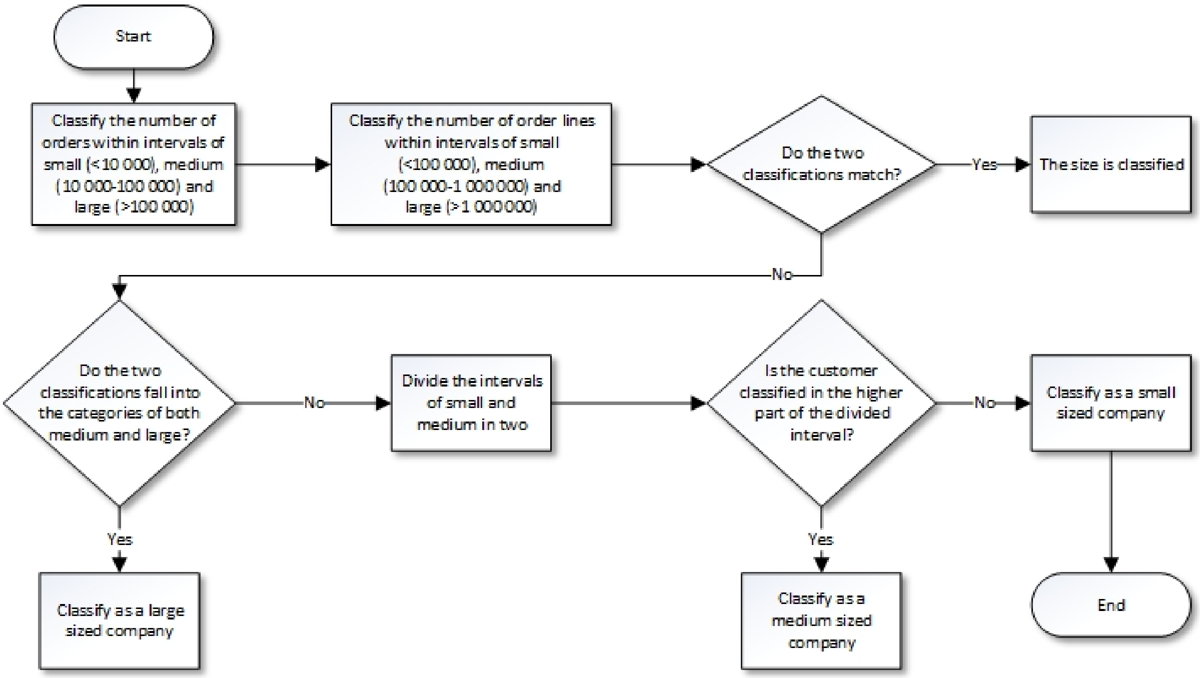


Figure 3. The flow chart of the process to classify size

In table 4 below, the final classification will be listed.

Table 4. The table shows the final classification of the customers according to the size factor.

Small	Medium	Large
Customer C	Customer A	Customer G
Customer L	Customer E	Customer H
Customer D	Customer B	Customer I
Customer F	Customer Q	Customer K
	Customer N	Customer P

8.1.2 Complexity

In order to assign the companies with different characteristics, definitions of the three variables, size, cut-off time and complexity, and their levels are analysed and determined. The variable of complexity will be considered as processes and tasks that differ from a generic outbound process of picking and packing. Since the thesis focuses on the outbound process, only the complexity according the outbound process will be determined although the inbound processes differ more and are considered as more complex than the outbound processes.

To determine the complexity of the different customers, the gathered data and the process descriptions in the empirical section are analysed and compared with the generic process to determine the processes that is added to the standard process. The standard picking process is illustrated in figure 4 while the standard packing process is illustrated in figure 5.

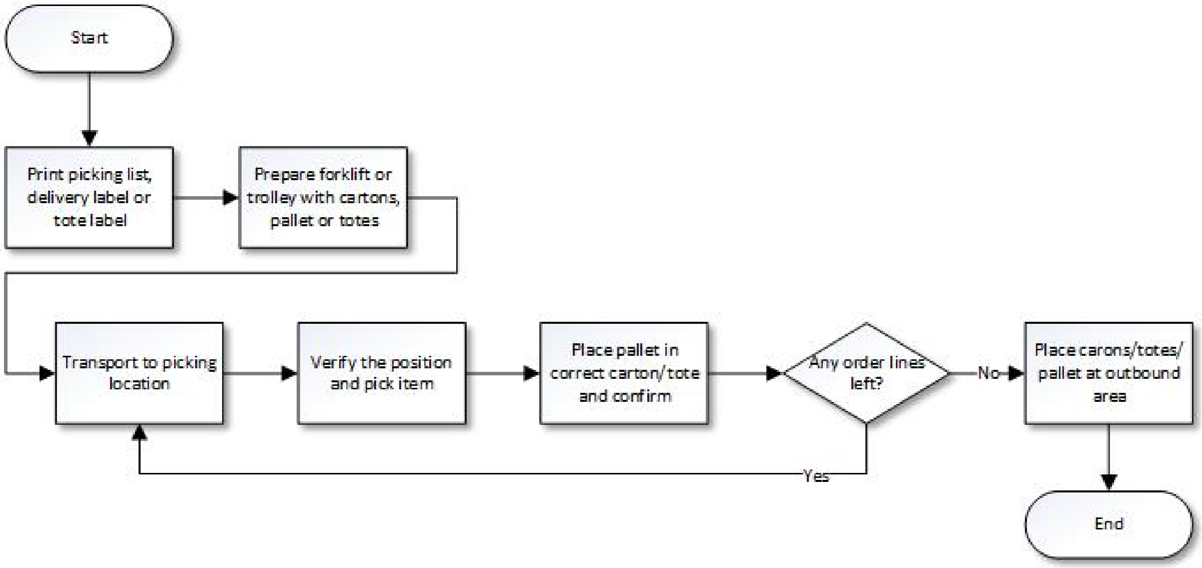


Figure 4. The figure shows the process flow of the standard picking process at SLOG.

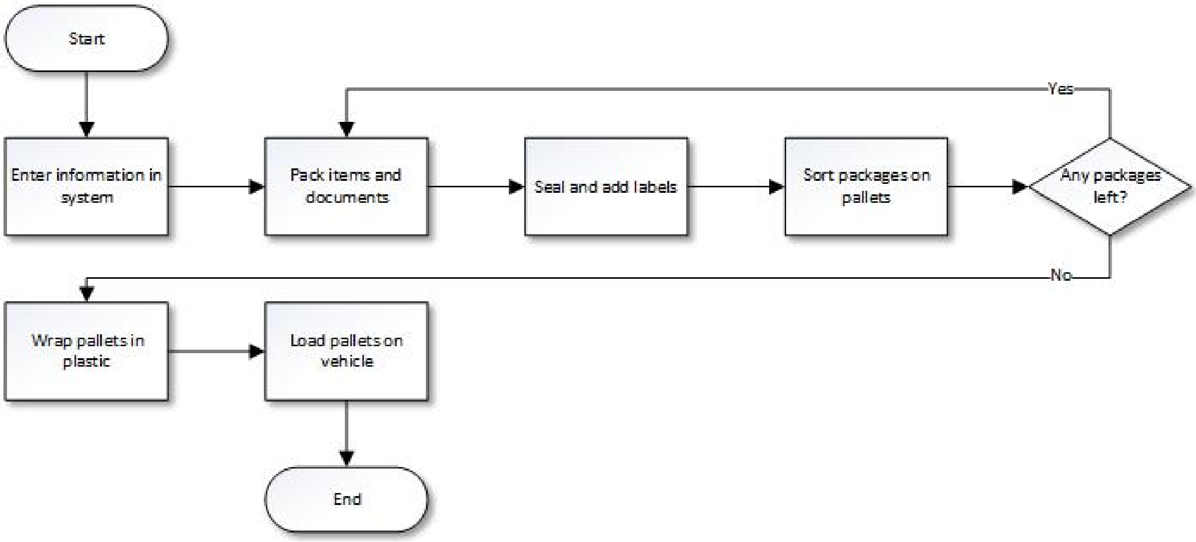


Figure 5. This process flow shows the standard packing process at SLOG.

Each additional process is analysed with the objective to determine its degree of severity. When deciding a tasks' severity several factors are taken into account, such as which level of experience the operator need in order to conduct the process and in which frequency the additional process occurs. Another factor impacting the complexity in the outbound process is the quality of the inbound deliveries. If the inbound delivery is of bad quality, soring of goods is needed. Items can in this process be mixed up, due to poor labelling, and end up at wrong shelve. This will be problematic when the operator is supposed to pick the item but it is not at the give position. In this case, a time consuming search for the error will start. Also the number of articles has shown to affect the complexity. The more article number, the more complex is the process.

It is the complexity of the additional processes, together with the quality of the inbound processes and the number of articles that are the basis of the aggregated level of complexity for a customer. The quality of the inbound deliveries are classified as good or bad while the number of articles are classified as few (article number less than 1000), medium (article number between 1000 and 5000) or high (article number more than 5000). In table 5 below, the factors that affect the complexity are listed for each customer at SLOG.

Table 5. The table provides the processes differing from the standard process, the quality of inbound delivery and the number of articles for each customer at SLOG. These factors are used as foundation for the classification of the complexity.

Company	Additional processes	Quality of inbound delivery	Number of articles
Customer A	Handling of returns, large part of e-commerce, store packages, special packing	High	Medium
Customer B	Nothing additional	High	Low
Customer C	Separate packing process	High	Medium
Customer D	Large amount of re-packing	High	Medium
Customer E	Pallet sorting to Mölnlycke on article number, weight/count papers	High	High
Customer P	Heavy goods (two persons needed), food standards, bulky goods, transport of e-commerce between ground level and mezzanine floor, dangerous goods (small part), priority of orders according to the time slots	High	Medium
Customer Q	Special handling equipment for the tunes, large part of dangerous goods	High	Low
Customer G	Additional packing process, large number of different articles	High	High

Customer H	Additional packing process, large number of different article, buffer space at ground floor, conveyor belt, high security zone	Low	High
Customer K (display packing not included)	Food handling, level picking	High	Low
Customer I	A lot of different zones, bulky goods, large number of article numbers	High	High
Customer N	Nothing additional	High	Medium
Customer L	Dangerous goods, special packing process according to the characteristics of the goods, transportation from the mezzanine floor	High	Medium
Customer F	Nothing additional	High	Medium

According to the number and the characteristics of the additional operation in the processes, the quality of the inbound delivery and the number of articles, a subjective assessment is made to divide the customers into the three categories: low, medium and high. The outcome is in this case dependent on the level of experience of the supervisors, solution design and business developers. The final classification of the customers at SLOG is listed in table 6.

Table 6. The table shows the final classification of the customers. In this table the customers are classified into three categories - low, medium or high complexity.

Low	Medium	High
Customer F	Customer I	Customer L
Customer N	Customer G	Customer H
Customer B	Customer D	
Customer C	Customer A	
Customer E	Customer Q	
Customer K	Customer P	

8.1.3 Cut-off Time

Cut-off time is, as described earlier, a kind of lead-time from the point in time when the last order is released to the point where the order should be ready to delivered and picked up by the transport company. This variable is defined in the contract and is specific for each customer. The classification of the cut-off time is divided into one short period of time and for this period the orders will arrive during the work shift. The main part of the companies has a cut-off time about 24 hours and the middle category is set between 8 and 24 hours. When the cut-off time is 24 hours, the labour scheduling for the next day can be done before the work shift is over. The last category considers the customers with longer cut-off time than 24 hours. For cut-off times between 24 and 48 hours, the labour scheduling have the possibility to be more precise since it spans two work shifts. Cut-off times longer than 48 hours are considered as more easy to plan and the companies that are using longer cut-off times are therefore not considered as a part of this study. The table 7 below shows the customers and their classifications according to the contracts.

Table 7. This table presents the cut-off times for each customer at SLOG.

1-8 h	8-24 h	24-48 h
Customer E	Customer D	Customer N
Customer C	Customer F	Customer P
	Customer K	Customer L
	Customer A	
	Customer B	
	Customer G	
	Customer H	
	Customer I	
	Customer Q	

8.2 Estimate Waste Time

From the calculation tool created by Frankin and Johannesson (2013), the theoretical time for a customers' outbound processes is conducted. By comparing the theoretical value with the actual time used during the processes, the factor of waste time is calculated. In order to create anonymous results, the data has been translated to index values where the base value is set to 100. The index of the calculated waste time for each company can be seen in table 8.

Table 8. This table shows the index of the calculated waste times for each customer at SLOG, where the base value is set to 100. The waste time is calculated by comparing the invoiced time and the theoretical time provided by the calculation tool made by Frankin and Johannesson (2013).

Company	Waste time
Customer P	29,4
Customer I	46,7
Customer L	55,0
Customer K	56,3
Customer B	68,8
Customer A	75,6
Customer N	77,9
Customer F	79,9
Customer G	88,0
Customer Q	88,8
Customer E	93,9
Customer H	100,0
Customer D	152,3
Customer C	160,7

The definitions of the three variables, size, cut-off time and complexity together form a 3D-diagram in the size of 3x3x3. In each and every box of this diagram a specific waste time factor can be set according to the defined customers in each category. The 3D-diagram is developed from table 4, 6, 7 and 8 and can be seen in figure 6.

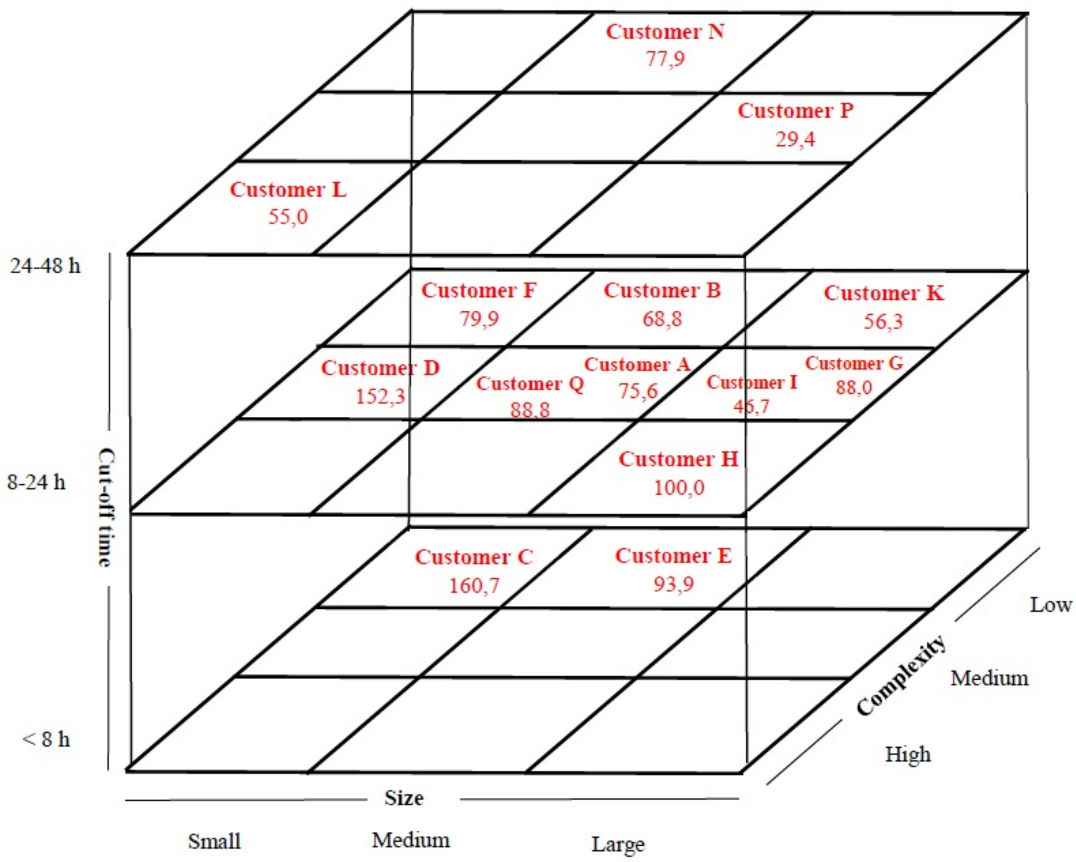


Figure 6. The size-axis stretches from small, medium and large, while the complexity-axis is divided into low, medium to high complexity. The cut-off time-axis has three intervals of 0-8 hours, 8-24 hours and 24-48 hours.

By starting to analyse the 3D-diagram containing the calculated waste times, some trends can already be seen. The majority of the 12 calculated values are located in the complexity-size plane, with a cut-off time 8-24 hours. When construing the values in the complexity-size plane, a trend of increasing in size correlates to a decreasing in waste time can be seen in two of three size-directions.

The waste time given by the theoretical time and the invoiced time provide 12 percentages of waste time, one for each current customer at SLOG. According to their characteristics, these percentages can be located in the 3D-diagram, as shown in figure 5 above. In order to detect correlations between waste time and size, cut-off time and complexity the remaining 15 cells also need values. These values are manually calculated by a multivariable analysis containing interpolations until the values stagnate. It took 15 interpolations until the values stagnated and the multivariable analysis yielded the waste time for the remaining 15 cells of the 3D-diagram that the current customers at SLOG do not represent. The values provided from the theoretical time and the invoiced time will further be referred to as *calculated values* and the values generated by the multivariable analysis will be referred to as *interpolated values*. Figure 7 shows the full 3D-diagram, containing both the calculated and the interpolated values. The values are presented as index related to the base value of 100.

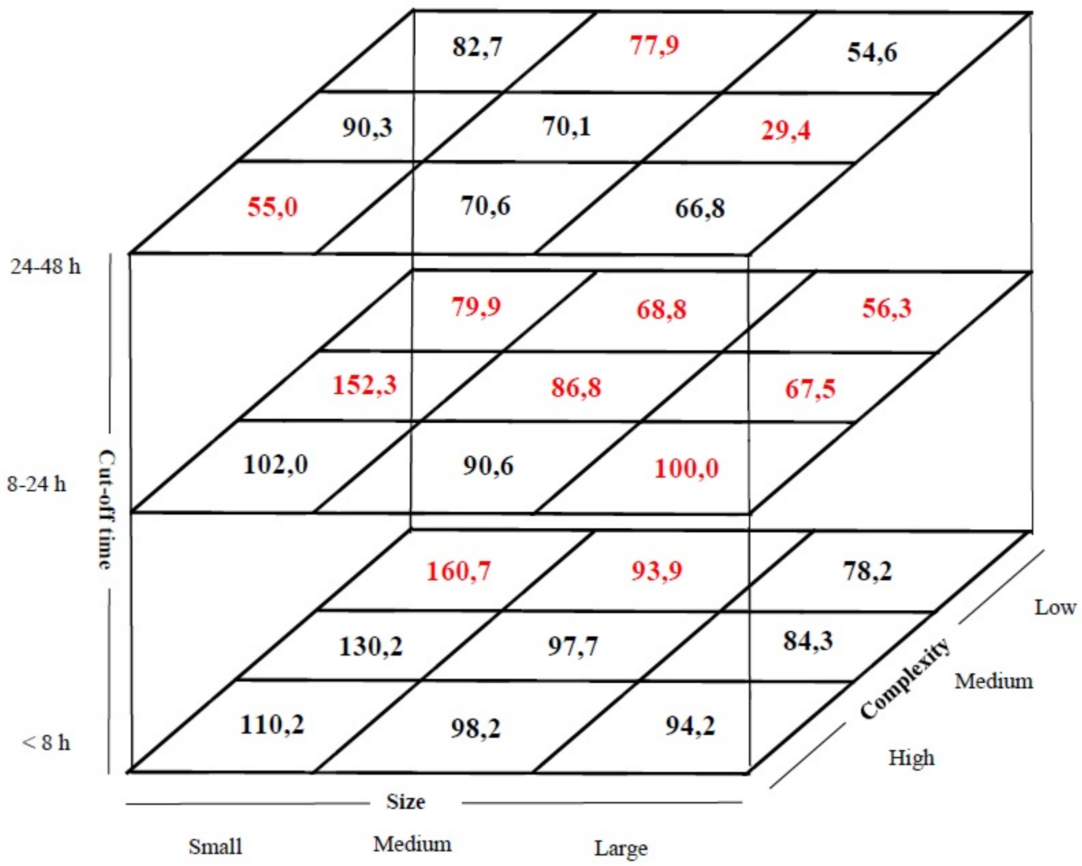


Figure 7. The figure shows the full 3D model were both calculated and interpolated values are shown. This 3D model will be used as foundation in the development of the calculation tool. The values are index numbers with the base of 100.

8.3 The Variable's Correlation with Waste Time

By adding the interpolated values, a further analysis can be conducted for the full 3D-diagram and each variable can be analysed separately. By distinguishing each variable and studying the values for waste time, increased size correlates to decreased waste time in 7 of the 9 possible cases. The remaining two cases showed no trend at all. When analysing the cut-off time, a correlation between decreased cut-off time and increased waste time was found in 5 of 9 possible cases. For the residual cases no trend were established. The weakest correlation was found in factor for complexity, where only 4 of the cases showed a trend towards a correlation between decreasing complexity and decreasing waste time. The remaining 5 cases did not show any trends at all. The final analysis of the 3D-diagram shows that the variable that has the highest impact on the waste time is the size, followed by the cut-off time and the complexity, which has the lowest impact.

8.3.1 Size's Correlation to Waste Time

When the size of the company is small, the number of staff needed for an assignment is often not an equal number. This means that the operators cannot work the whole day at the same assignment since there are not enough incoming orders. The operator then have the option to stay at the current customer and wait for incoming orders or to change assignment and change to a customer that have unpicked orders in line and needs more operators. In order to change assignment, the operator need to transport himself or herself to another customer, find the team leader and get work instructions before the picking at the new customer can start. In this process waiting, unnecessary motion and unnecessary transport are added to the process. According to lean, these are referred to as 3 of the 7 wastes that need to be reduced in order to streamline the process (Eaton, 2013). By instead, as for the case of small customers and assessments, adding these activities rather than reducing them, the waste time will increase and thereby a correlate to the actual size of the customer can be seen.

What is wanted, is to smoothen the demand to reach an even number of staff. This can, according to the labour scheduling method of leveling be done by handle an average demand over time instead of handle the uneven demand just in time (Reyner & Flemming, 2004). By smoothen and increase the demand, as the principle of leveling advocates, the waste time will be decreased. Merging smaller customers into one and, from perspective of picking and packing, treat them as a larger customer will in that case increase the volumes, the labour scheduling will be simplified and waste time can be reduced.

8.3.2 Cut-off Time's Correlation to Waste Time

In 5 out of the 9 cases, a shorter cut-off time indicates larger waste time and by this, the cut-off time is the factor with the second largest impact on waste time.

A reduced cut-off time indicate with an increasing waste time. Inventory processes with reduced cut-off time relates to increased difficulty in planning for an unknown demand. Cut-off times shorter than 8 hours have the highest waste times. In this case the orders are released during the work shift the same day as they will be delivered. It actually means that also the labour scheduling needs to be done during the day. According to the working conditions from the union, the manning workers need to be called in at least a couple of hours in advance. This results in that the planning and labour scheduling not can be done the same day and therefore the planning need to be based on forecasted and historical demand. The high rate of unknown demand limits the ability to optimize the labour. The supervisors indicate that it is more common to increase the capacity rather than improve the productivity to be able to deliver all of the possible incoming orders and keep the service level high, which results in extra staff. This would be one factor for the correlations between decreased cut-off time and increased waste time. For cut-off times in the interval of 8-24 hours, the labour scheduling can in a best case scenario be arranged the day before the order delivery. In this case, the demand is known before the work shift is over and the supervisors have time to plan for the next day. In this cut-off interval, the orders are not always totally set and some changes can be made during the next day, which are hard to plan for.

For cut-off times longer than 24 hours, the scheduling can be done on actual demand since the orders already are released at the time for labour scheduling. This will simplify the process significant and by labour scheduling to meet the demand, the waste time will be reduced.

The cut-off time is an input given by the customer and nothing that SLOG itself can affect in other way than in the pricing. A shorter cut-off time will generate a higher price per operation since the waste time is included in the price.

8.3.3 Complexity's Correlation to Waste Time

The complexity of the outbound process shows that in 4 out of 9 cases, a correlation between high complexity and an increase of waste time. This gives the indication of that complexity is the variable with the weakest impact on waste time out of the three defined variables.

The customers at SLOG have their own customized storage area. In the design of this area, the complexity is taken into consideration and the impact of the factor is thereby reduced during the design process. This means that the effect of complexity is not shown to the same extent as the other variables of size and cut-off time. If a standardized outbound solution would be applied for all customers, the variable of complexity would have shown greater impact on the waste time.

8.4 Markets Opinion of Standard Inventory Solution

Today, the majority of all inventory solutions is customized and holds investments (Kolderup-Finstad, 2014). Therefore, in order for SLOG to find a customer interesting, the volume and frequency of the transactions is of great importance in order to secure profitability. This creates limitation for SLOG and other 3PLs. The conclusion from the calculation tool and according to Frankin and Johannesson (2013) is that the size is of great importance when reducing waste time. In order to reduce the waste time, inventories can be merged into a standardized warehousing process and treated as one customer. Merging customers creates larger volumes and reduces waste time.

With standard inventory solutions, customers with lower volumes, small order sizes but high frequency will also become an interesting segment. In connection with the sales process and the first step of "Go / No go", SLOG will be able to achieve business cases with a larger amount of customers.

8.4.1 Strategies and Incentives for the Companies Current Logistic Solution

The markets opinion indicates strategies and concerns regarding their current logistic solution and provides guidelines for future possibilities and barriers for solutions with merged inventories. The division between companies using in-house and 3PL was done in order to visualize potential sector specific considerations regarding a standard inventory solution.

The opinion from the studied market was united in the majority of issues and scattered in a few questions. There was a unity regarding the most important factors in logistics services. The most essential factor was considered to be the price of managing the inventory processes, as the market agreed with Richards (2011) that warehousing is only seen as cost drivers. Logistics service is a low margin business and price is a great challenge for the warehouse business. Logistic companies are dealing with difficulties concerning operating cost efficient while providing high customer service. This challenge is related to the fact that quality of logistic services is also highly rated by customers. All of the interviewed companies considered quality as vital part of logistic processes. The relationship with the entity that manages the logistic services was mentioned by a minority of the companies. For companies with a current solution of in-house, a long term relationship was of great value. Companies with 3PL mentioned communication in connection with relationship. These two approaches reflect their current need of relationships with their logistic providers, as in-house logistics provides a basis for a solid relationship. Meanwhile, a successful collaboration with a 3PL often demands transparency between the customer and the 3PL (Richards, 2011)

When comparing the companies' reasons for using their current logistic solutions, users of in-house solutions emphasized the ability to control the entire process, as well as ensuring good quality. In-house solutions were considered to allow the company to adapt their business plan on the logistic processes, which contributes to a holistic approach. Companies using in-house solution indicated that customization is essential and this concern was also raised regarding their perception of having merged inventories. The main concern was also the ability to retain a high priority for their processes.

In contrast to companies with in-house solution, 3PL users expressed economic incentives for using 3PL providers. To reduce prices, take advantage of economies of scale and competence were considered as the main reasons for the chosen strategy. A minority of companies also expressed the perception that 3PL companies have a higher possibility for development of inventory solutions. The companies using a 3PL provider also pronounced worries about the difficulties in merging processes, since a lot of products were considered needed specific handling requirement. Furthermore, the worries of not being able to keep a high service level and deliver, not only wrong products, but also another customers products according to mix-ups were seen as the largest obstacle for a merged standardized inventory solution. Some customers, however, expressed no worries at all about this fact. They meant that they do not care about how it is provided as long as they get what is promised.

8.4.2 Possibilities and Barriers for Merged Automated Inventory Solutions

Both segments mentioned that their current knowledge regarding automated solution was very basic, as the business development managers at SLOG also mentioned. The basic knowledge could be explained by the companies not having the financial ability to invest in automation and therefore not investigated the possibility further. For in-house companies an automated solution would require a large investment and for 3PL companies a large investment in inventory would also require an extended period of contract. This becomes a closed cycle argument for 3PL-using companies, since the 3PL offers a great flexibility (Reif & Günthner, 2009).

The majority of stated considerations from the market concerns quality, capacity and increased transparency from other companies. Todays customized solutions allows each company to have their own, more or less, dedicated operators in their inventory. A merged inventory would not provide that service. But using an automated solution, dedicated operator would not be required in order to manage the inventory process. As Sparf (2014) mentions, the automated solutions are customized with the customer's specific requirements as a basis. Managing fragile products or grocery products is not considered as barriers for an automated solution. In the case of specific requirements regarding size a parallel process will be customized, which will be managed by the operators. As the products will be managed simultaneously in the same processes, the possibility to deliver fault products was also raised as a concern. Hompel and Schmidt (2007), states that using picking techniques such as hand scanner, pick by light and pick by voice gives an accuracy rate around 99,5%, 99,7-99,97% and 99,7-99,97%. Automated inventory solutions demonstrate accuracy rates in the same levels and a high quality is maintained (Sparf, 2014).

The capacity was also considered as a barrier for the market. Concerns regarding reduced priority and increased cut-off times during peak seasons were stated. This dilemma is a current challenge for warehouses, especially with increased e-commerce, which demands a more narrow time window for warehouse processes (Richards, 2011). When designing a customized inventory solution, either for in-house or 3PL, capacity analyses are conducted in order to meet great seasonal variations (Richards, 2011). When designing an automated inventory solution similar capacity analyses are conducted and the method of doing that does not differ from the way of analysing capacity for a manual warehouse solution. The capacity of an automated inventory solution is easy to increase, as the solution uses consistency in equipment and allows expansion. When the system is running and more capacity is needed, components such as robots and sorting stations are rather easy to add to the system (Sparf, 2014). However, new investments come with this option.

The third main factor for possible resistance for merged inventories was the perception of increased transparency for the companies. Concerns regarding other companies receiving a valuable insight in the inventory process, which could reveal strategic business moves such as special offers and products. The problem with competition among companies in a warehouse could be narrowed down to companies with the same seasonal variations, product range and markets. Companies with in-house logistics will definitely be more exposed to competitors. Companies using 3PL providers already share the warehouse with other companies, and are in a similar situation as with merged inventories. The situation with shared processes should not affect the situation. If companies experience intense competition with a certain segment of companies, a collaboration with a merged inventory nor 3PL might not be of interest. The circumstances if the companies use a merged inventory or the same warehouse by a 3PL should not make any difference.

As mentioned before, an automated inventory solution requires great investments. For the moment 3PL providers have a standard of providing contracts for 2-3 years. This premise is based on customer requirements for flexibility and possible options to change logistic services. The contract periods are a limitation for development and represent short term solutions which do not reach full potential. As the 3PL providers operate in a business with low marginal (Richards, 2011), a 3PL is not able to invest in an automated inventory solution without a secure and stable demand. The business development managers state that the mean customer uses the same 3PL company for 7 years, with renewed contract every second year. This indicates that a company could allow an extended period of their original contracts. An extended contract would result in a more stable relationship and greater opportunities for development and investment (Andersson et. al, 2001). In the current contracts between the 3PL provider and their customers, a 50% ramp up in productivity is calculated for the first 6 months. The reduced productivity is based on the time it takes for the warehouse operation to be fully implemented and the start-up issues are solved. During this period the operators will learn the new customized inventory processes and the information and collaboration between the 3PL and the customer are established to function on a high level (Kolderup-Finstad, 2014). An extended contract would allow security and ability to develop a cost efficient automated inventory process, and reduce start-up costs for new implemented customers at the warehouse of a 3PL.

9 Discussion

As stated by Frankin and Johannesson (2013) and verified in this study, low volume of transactions in the number of order and order lines correlates with increased waste time. The analysis of the 3D-diagram also indicates a correlation between reduced cut-off time and increased waste time. Since waste time limits the possibility to operate cost efficient, both volume and cut-off time are important factors and should be taken into considerations when designing an inventory solution. A proven method for smoothening demand in production is *leveling*, which aggregates the demand over a certain period (Reyner & Flemming, 2004). To obtain leveling for inventory solution one possibility is to merge several customers in order to achieve greater volume. The merged inventory creates larger volumes and a smoothening demand. For customers with small volumes the waste time is high, as factors such as allowances have greater impact. The allowances contain time for work instructions from team leaders, brakes, social activities, physical or mental strains, minor machinery maintenance, deviations etc., (Das, 1990). In the total waste time, the waiting time for new orders to arrive is also included. It is especially the time for new instructions and the waiting time for new orders to arrive that decrease when the volume increases, since the demand becomes more stable and time waiting for instructions and orders will be reduced.

As stated, both in the empirical findings and in the literature review, the ability to manage a cost efficient labour scheduling is limited of the fluctuating demand (Harvey, 1998). Thompson (1998), describes the dilemma as choosing between high productivity and high customer service. The ability to respond quickly to customers' request represents an essential part of a company's customer service. Allowing short cut-off times result in an uncertainty in demand, which is hard to predict and to plan for. *Leveling* would decrease the fluctuations and create a more stable demand. When merging customers, the short cut-off time would not affect the processes to the same extent as it does today. In the merged inventory, the operators can focus on the orders with the longer cut-off time until orders with shorter cut-off time are released. When that order is picked, the operator continues with the orders of longer cut-off time. In this way, the time spent from the operators waiting for incoming orders will be reduced, since a mixture of orders with different cut-off times always are provided and the waste time will therefore be reduced.

The analysis also indicates a weak correlation between complexity and waste time. The result of this trend is, however, questionable since the trend is weak. Furthermore, the processes are design in order to reduce the complexity and ease the operations. This could also be a reason for the difficulty to determine the level of complexity and therefore also result in a questionable result.

9.1 Reliability and Validity

The starting point, for estimating the degree of complexity, was to define a standard outbound process. Processes that deviated from the standard process were considered more or less complex. Also the number of articles for a customer and the quality of the inbound process was used as an input in determine the complexity. The degree of impact of the three factors for complexity were conducted subjective together with solution design, supervisors and team leaders. The factor for complexity therefore becomes a subjective measure with a low reliability since the same degree of complexity might not be achieved when another sample group, with other experience, of solution design, supervisors and team leaders are involved

(Allwood, 2004). There is a general criticism for case studies regarding whether the data collection is done subjectively or not. It is stressed that for open interviews, which was the case in this study, it is of great importance that the responses and personal views are equally valued (Yin, 2009). The difficulties for the authors were to distinguish between personal views and responses, and with this both the level of reliability and validity for the deviation of complexity can become questionable. In order to create reliability of the thesis, several interviews were therefore performed to obtain multiple information sources. Since the response pointed in the same direction, the study is considered having reliability. Furthermore, the reliability and validity of a study are affected by both systematic misinterpretations and general misstatements (Yin, 2009). In this study, these factors could be represented by systematic misstatements in interviews. The respondents can designate certain practices with terms that can be perceived differently by the interviewer. In order to minimize these misinterpretations, ambiguities were questioned and the interview questions were supplemented with queries to specify the specific term used.

When defining the other two factors, size and cut-off time, a more quantitative method were used. Both size and cut-off time was defined with numerical data. When using a quantitative method the reliability is ensured in a higher extent (Allwood, 2004). In the process of defining the size and how it should be measured, a discussion concerning which factors the size would be based on was held. Factors such as the actual space of the goods and the financial turnover were reviewed. These factors were considered not to indicate the actual volume of transactions and the related work amount demanded, and was therefore dismissed. The option left was to base the size on flow and transaction, which lead to the usage of number of orders and order lines as the foundation for the factor of size. Consequently, both the reliability and validity of the size are considered to be assured. The cut-off time was predetermined for each customer, but in order to determine an interval for the three-point scale a qualitative process was used. For this process, information from both supervisors and operators regarding how the cut-off time affects the work was taken into consideration. As mentioned above, a method to create reliability, perceptions from several operators and team leaders were taken to into account. Hence, also the analysis of cut-off time is considered having validity and reliability.

The results of the thesis have continuously been discussed with supervisors at both Chalmers University of Technology and at SLOG. By constantly monitoring the work and conducting frequent reconciliations with the parties involved, the validity of the results increases.

9.2 Factors Affecting the Differences in Waste Time

When analysing the waste time for the different customers, the factors of size, cut-off time and complexity are in some cases very similar but the waste time vary anyway. That indicates other impacts on waste time than the three given factors. As waste time includes the time it takes for operators to go to and from specific areas for breaks and toilet visits, the design of the warehouse becomes essential. By studying the layout of the warehouse and where in the building the customers operate, it becomes clear that also the distance of movement for the operators contribute to increase waste time. By comparing customers with similar picking and packing processes and similar levels of size, cut-off time and complexity, it becomes obvious that the location of the inventory of the customer has a great impact of the waste time. Customer A and Customer G can be used as an example. The inventory of Customer A is located as the first customer in the warehouse building, with the closest distance to the break area and the station for checking in and out. Customer G, with its similar processes, is located in the other end of the building. This means that a distance of around 400 meters needs to be walked in order to reach the break area and the station for checking in and out. For the operators who have one lunch break and two pauses, it becomes at least 3200 meters per day. The time it takes walk this distance is contributing to the total waste time. A comparison of the calculated waste times for Customer A and Customer G shows that Customer G, a large size customer, has greater waste time than Customer A, which is considered as a medium sized customer. The difference in distance that needs to be walked every day can be seen as a possible driver for the greater waste time at Customer G. By taking the waste time into consideration already while designing the buildings can therefore contribute to lower levels of waste time. When assigning storage space for the customers, an analysis to generate the most labour intensive customers is desirable. To reduce the waste time, these customers should be placed strategically in order to minimize the walking distance to break areas, toilets etc. and in this way minimize waste time due to unnecessary transport and movement (Eaton, 2013). In the situation at existing buildings, as in the case of SLOG, the possibility of moving the break area closer to the working area can be investigated in order to reduce the contribution of unnecessary transport and movement from the total waste time.

An additional factor that will affect the waste time is the turnover of the operators working at the assessments. Every operator has a customer that they spend the majority of working hours on. The reaming time is spent on customers that need extra support for a limited time. As SLOG calculates a loss in efficiency of 50% for the first 6 month when offering a new inventory solution, a comparison could be done related to the rate of productivity between experienced and novice operators. All the efficiency loss cannot be connected to the operators' level of expertise, as the majority of loss is linked to the process itself where several units are involved. But since an experienced operator will most likely have a higher productivity, a high turnover of personnel will affect the productivity negatively and a higher level of waste time will arise.

9.3 Merged and Automated Inventory Solutions

Today, the trend is towards a more automated environment in warehouses (Hamberg & Verriet, 2012; Sowinski, 2013). The trend relates to the fact that logistics and warehousing are businesses with low margins and increased global competition (Richards, 2011). Developing warehouse solutions with a higher rate of automation reduces the amount of labour, which is the main cost driver (Wulfraat, 2014). Reduction in labour cost will partly be replaced by investments in equipment, but as automated solutions have a higher productivity (Sowniski, 2013). This will result in long-term cost reductions. The empirical data, confirms that the market has a very basic knowledge regarding the possibilities of an automated inventory solution. The majority of stated reflections from the market concerns quality, capacity and increased transparency from other companies. The stated concern regarding reduced quality of the picking and packing processes are unwarranted, as the automated solutions provides the same level of high quality as the traditional picking techniques.

Concerns regarding the priority and capacity of an automated inventory solution, which is used by several customers, were also raised from the market. When the inventory solution is designed, analysis of the order pattern and needed capacity is done (Sparf, 2014). This will be done for the original set of customers that will use the common inventory. When customers choose to change solution or 3PL provider, new customer can be added in the merged inventory. In this case, the 3PL company has a responsibility to analyse which customers that are suitable for the merged inventory. Other factors that need to be taken into consideration regarding the aggregated inventory are order patterns, seasonal variations and appropriate characteristics of the goods for the customers in the merged inventory. It is desirable to have variation in seasonal demand and order pattern to be able to smoothen the demand over time and prevent demand peaks. The characteristics and geometry of the goods, on the other hand, are desirable to be as similar as possible to further standardize the process.

The methods of increasing or decreasing capacity differ between automated and manual warehouse solutions. Therefore, considerations need to be taken regarding how to meet the need of increased capacity. Evaluations regarding short-term solutions of increasing the number of operators, versus long-term solution through increasing the capacity by redesigning the solution, should be conducted. For manual inventory solutions, increased number of operators during office hours would to one extent increase the capacity, but the cost of extra labour would not have a linear relationship to capacity. This, since adding operator also results in the queues and poor accessibility. In Sweden, the labour cost for non-office hours is high which results in high expenses for shift work. The ability to increase capacity in an automated inventory solution depends on the design of the system. Adding an extra shift for automated solutions is also considered as a short-term solution. A long-term solution is to redesign the building to be able to increase the capacity. The systems are often designed for an overcapacity since this not generates huge additional costs relative the start-up cost for the system. The options are therefore to increase the usage of the current capacity and add extra work shifts, or increase the number of operators. The ability to increase the capacity in short term is, however, more limited for an automated solution than for a manual inventory solution since some components need to be added to the inventory solution in order to maintain an increased capacity.

The increased transparency between customers is also experienced as a major problem. The situation of sharing inventories with other customers puts pressure on the 3PL provider to be able to create guidelines for how the customers are allowed to enter the warehouse and check their inventory.

As in several other situations, it is always considered to be most risky to be first out. When the concept of merged inventory solutions is widely spread, 3PL providers can use successful reference objects in order to convince new customers into join the concept. With increased knowledge, the companies might see the possibilities rather than the barriers. Furthermore, a greater extent of customers using a merged automated inventory solution results in a reduction of investments for each customer. As it is the customers that hold the investments in 3PL solutions, the investment cost will be reduced since the costs are shared among more actors. With reduced investment, the 3PL company has the possibility to provide contracts with shorter contract periods, which is in line with the demand of flexibility from the market.

9.4 Recommendations

In the section the recommendations for SLOG will be presented. Important aspects to have in mind while using the calculation tool will be presented together with some general recommendation.

9.4.1 Usage of the Calculation Tool

The calculation tool will be a support for the solution design team at SLOG when estimating labour demand while conducting offerings for new or existing customers. The calculation tool is implemented in an existing, internally used excel file used for calculations on offers. The first input for the calculation tool is the three variables size, complexity and cut-off time. The variables are divided in three-point scales. The size has an interval considered as small, medium and large companies. The intervals relates to the volumes of order lines and orders. A company with a volume of order between 0 -10 000 and order lines between 0 - 100 000 is considered as small. A company having 10 000 -100 000 orders and 100 000 - 1000 000 order lines is considered medium. Large companies have more than 100 000 orders and 1000 000 order lines. For companies where the number of orders and order lines not fall into the same interval, the flow chart previously shown in figure 3 is used in order to find the right classification of the size variable.

The second input is the complexity, which has an interval stretches from low to medium to high. In order to determine the complexity for a company, the user of the calculation tool need knowledge concerning which processes that deviates from the generic picking and packing process defined in figure 4 and 5. Since the classification of the complexity is based on a subjective assessment, it is recommended for the user to discuss the chosen classification with other, experienced persons in order to increase the validity of the decision.

The third input, cut-off time is a variable set by the customer and in the calculation tool three different intervals can be chosen. The shortest interval is of 0-8 hours followed by 8-24 hours and 24-48 hours.

When the decision is made regarding which parameters used as input, the calculation tool displays a percentage of waste time. This percentage should be added onto the calculated time for the new possible assignment. The calculation tool will generate both the calculated time needed for the processes, the waste time according to the given input of size, complexity and cut-off time, and the total time including waste time for the processes of the new possible customer or the existing customer. The design of the calculation tool, without any inputs, can be seen in figure 6 below.

Overall manual labor need

Reception hours:		*0,0*
Put away hours:		*0,0*
Total time inbound:		0,0
Picking hours:		*0,0*
Packing hours:		*0,0*
Total time outbound:		0,0
Minimum required hours:		0,0
Time allowances:		0,0
Size of customer:		0,0%
Complexty of processes:		
Cut-off time:		
Total FTE / day (incl. allowances):		0,0000
Total required hours (incl. allowances):		0,0

Figure 8. Example of the calculation tool. The tool will generate the times for the reception, put away, picking and packing processes and calculate the required time. By setting the parameters of size, complexity and cut-off time, time allowance will be calculated and the total required hours will be calculated.

The user of the tool always needs to validate the output and estimate the plausibility. Recommended is to discuss the output with colleagues in order to validate the output and prevent incorrect calculations.

9.4.2 General Recommendations

Some recommendation in general will be given to SLOG in order to reduce waste time. The design of the building and how the customers are arranged inside the building have in this thesis shown impact on the waste time. One thought, for SLOG, to have in mind while assigning storage space to customers is to place the most labour intensive customers closest to the check in and out stations. In this way, the aggregated waste time can be reduced since less operators need to be transported the long distances that comes with large warehouses.

As the conclusion of the analysis states, the variable of size has the greatest impact on waste time. By increasing the size of the customer, according to number of orders and order lines, the waste time can be decreased. In this thesis, the principle of merging smaller customers and treat them as a larger one is recommended as one solution to the problem. The recommendation is to start with a smaller pilot project where non-complex customers with stable demand participate. In this way the possibilities of the solution can be investigated in reality and at the same time possible obstacles can be solved. When the pilot project is running smoothly it can be used as good reference during the sales process when new customers are needed to be able to implement the solution in full scale.

As the trends go towards automated warehouse solutions, it is recommended to look at possibilities to implement an automated solution. The market research study, made in this thesis, shows that the majority of the customers today are not willing to pay extra or extend contract periods in order to be provided automated solutions. To be able to attract customers to the new automated solution SLOG need to emphasize the possibilities with automation, e.g. increased productivity and decreased labour costs. The automated solutions are often build to be able to handle different customers at the same time which encourage the merged inventory solution. An implementation like this would not only decreased the waste time and increase the productivity, but also increase the reputation of SLOG as a prominent developer within the business.

10 Conclusion

The calculated times needed for labour differs from the actual labour demand, defined by invoiced time for the customers, with up to 60 percent. Increased size of a customer, e.g. increased number of order and order lines, has the highest correlation to reduced waste time. The analysis also established a correlation of increased cut-off times and decreased waste time. Furthermore, the analysis indicated a weak correlation between decreased complexity and decreased waste time. The correlation was shown in less than half of the possible cases. As both increased size and cut-off times showed strong trends related to reduced waste time, the principles of leveling can be used by merging several customers. This will lead to reduced waste time and increased efficiency due to smoother, non-fluctuating demand. The most suitable characteristics of the customers in the merged inventory solution are companies of small size and various complexity, dissimilar seasonal variations and no distinct competition. Also the type and shape of the goods should be similar in order to ease the handling. Using an automated standard inventory solution is proposed when merging customers, since the trend for warehouses is towards an increased use of automation. The markets' knowledge regarding automated inventory solutions is considered as being very basic at the moment. This creates barriers for implementing the solution but increased knowledge regarding the possibilities with an automated merged inventory solution will allow future implementation.

10.1 Further research

The main focus for this study was to develop a calculation tool to support the decision regarding the labour demand for new assignments. A merge of companies was proposed in order to achieve leveling and increase efficiency. When merging companies, no considerations regarding the fact that the design of the processes itself could contribute to unnecessary waste time was taken into consideration.

Further research regarding what operations within a process drives the waste time and how to reduce these sequences can need to be further investigated. This study mentions allowances that are considered as waste and can be reduced, but is not possible to fully eliminate. There is a different between waste time, that is desirable to reduce, and "necessary" waste time, such as breaks and time for getting work instructions. It would be of interest to further investigate the proportion of the pure waste time and the "necessary" waste time to be able to confirm the minimum allowance needed for each process. This investigation will also give a holistic view of which processes that are most inefficient and need future development.

This study indicated a weak correlation between complexity and waste time. Further research in defining the degree of complexity and developing a framework for defining different levels of perceived complexity would give another dimension in what drives waste time. It would also be of great interest to study additional variables, and how these would affect waste time. As mentioned in the discussion above, factors such as the turnover of the operators might have a great impact on waste time, since a learning curve must be taken into consideration when calculation productivity and waste time.

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Appendix I

Appendix I presents the persons that were interviewed in the study.

Table 9. In this table the persons at the different customers at SLOG are presented by position, customer they are working for and location of the warehouse.

Position	Customer	Location
Design Solution Manager	Schenker Logistics	Landvetter
Supervisor	Customer A, Customer C, Customer B, Customer E, Customer D, Customer F	Landvetter
Supervisor	Customer I	Landvetter
Supervisor	Customer H	Landvetter
Team Leader	Customer A	Landvetter
Blue collar	Customer A	Landvetter
Blue collar	Customer A	Landvetter
Team Leader	Customer C	Landvetter
Blue collar	Customer C	Landvetter
Blue collar	Customer C	Landvetter
Blue collar	Customer B	Landvetter
Blue collar	Customer B	Landvetter
Blue collar	Customer D	Landvetter
Blue collar	Customer D	Landvetter
Blue collar	Customer E	Landvetter
Blue collar	Customer E	Landvetter
Blue collar	Customer F	Landvetter
Blue collar	Customer F	Landvetter
Blue collar	Customer G	Landvetter
Blue collar	Customer G	Landvetter
Blue collar	Customer G	Landvetter
Team leader	Customer I	Landvetter
Blue collar	Customer I	Landvetter
Blue collar	Customer I	Landvetter
Blue collar	Customer I	Landvetter
Blue collar	Customer H	Landvetter
Blue collar	Customer H	Landvetter
Blue collar	Customer H	Landvetter
Blue collar	Customer H	Landvetter

Team Leader	Customer K	Arlanda
Blue collar	Customer K	Arlanda
Team Leader	Customer N	Arlanda
Blue collar	Customer N	Arlanda
Team Leader	Customer J	Arlanda
Blue collar	Customer J	Arlanda
Team Leader	Customer L	Arlanda
Blue collar	Customer L	Arlanda
Blue collar	Customer L	Arlanda
Team Leader	Customer O	Arlanda
Blue collar	Customer O	Arlanda
Blue collar	Customer M	Arlanda
Supervisor	Customer P	Jönköping
Supervisor	Customer Q	Jönköping
Supervisor	Customer R	Jönköping

Table 10. The table lists the persons interviewed in the field studies. The names, position and at which company they work are presented.

Position	Company	Current warehouse solution
Plant Logistic Engineer	Volvo Cars	Manual In-house
Plant Logistic Engineer	Volvo Cars	Manual In-house
Plant Logistic Engineer	Volvo Cars	Manual In-house
Production Manager	Kappahl	Automated In-house
Team Leader	Lindex	Automated In-house
Head of Sales & Consulting Solutions	Swisslog	Selling automated warehouse solutions

Table 11. This table present the persons interviewed in the market survey. The table presents the position of the interviewed person, which business the company belongs to and the current warehouse solution the company has.

Position	Branch	Current warehouse solution
Business Developer Manager	Schenker Logistics	
Business Developer	Schenker Logistics	
Supply Chain Manager	Electronics	In-house
Logistics Manager	Consumer	3PL
Logistics Manager	Fashion/Retail	3PL
Logistics Manager	Fashion/Retail	3PL
Logistics Manager	Fashion/Retail	3PL
Logistics Manager	Fashion/Retail	In-house
Logistics Manager	E-commerce	In-house
Logistics Manager	E-commerce	In-house
Logistics Manager	E-commerce	In-house
Supply Chain Team Leader	Automotive	3PL
Logistics Manager	Automotive	In-house

Appendix II

In this appendix the questions for the interviews in the market survey are listed. Interviews with 11 companies from 5 different type of businesses were held. All interviews were anonymous.

What is your position at your company?

GENERALLY

- What is your inventory solution today? In-house or 3PL?
- Why have you chosen that solution / strategy?
- What strengths / weaknesses do you see in the current inventory solution?
- Are you looking for other inventory solutions?
- What do you think is the most important factor in warehouse operations? Price, quality, relationships etc.?
- What is your contract term?
- Why that specific contract term?

STANDARDIZED INVENTORY SOLUTIONS

- What do you think about sharing stock with other companies? Pros and cons?
- What possibilities can you see with a standardized solution which is not unique to the customer, where the warehouse processes instead are shared with other clients and provides a cheaper price?
- What kind of other companies would you be able to store shared with? (Companies within the same segment/competitors, seasonal variations, etc.).

AUTOMATED WAREHOUSE

- How familiar are you with the automated warehouse solutions?
- Do you discuss the future usage of automated warehouse?
- Within what period of time do you think you will invest and use automated warehouse solutions?
- If using 3PL, are you interested having longer contract terms to be able to cover the investments for an automated solution?

Appendix III

Picking	Input	Unit	Time seconds		Time hours		Comments
1. Initiate picking route							
Type of printing technique							
No. of routes		routes	0	s	0,0	h	
2. Prepare picking vehicle							
No. of order routes with cartons		routes	0	s	0,0	h	
No. of order routes with totes		routes	0	s	0,0	h	
No. of routes with pallet/trolley		routes	0	s	0,0	h	
3. Transport during picking route							
Alt. 1							
Type of transportation							
No. of order routes		routes					
Average transport distance per route		m	0	s	0,0	h	
Alt. 2							
Type of transportation							
No. of order routes		routes					
Average transport distance per route		m	0	s	0,0	h	
Total time			0	s	0,0	h	
4. Vertical positioning to item location							
Type of transportation							
No. of order lines		order lines					
Average positioning height (up and down)		m	0	s	0,0	h	
5. Order line/number of stops							
Type of picking technique and aisle							
No. of order lines		order lines	0	s	0,0	h	
6. Picking							
No. of single pallets		pallets	0	s	0,0	h	
Pick item							
No. of picks		picks					
Average depth of pick		mm					
Average weight of item		kg	0	s	0,0	h	
Total time			0	s	0,0	h	
7. Position items to packing area							
No. of cartons or boxes		cartons	0	s	0,0	h	
No. of pallets or trolleys		pallets	0	s	0,0	h	
8. Additional inputs							
Additional inputs			0	s	0,0	h	
Total time picking			0	s	0,0	h	

Packing	Input	Unit	Time second		Time hours		Comments
1. Initiate packing							
Type of picking technique							
No. of customer orders		orders	0	s	0,0	h	
2. Enter information in system							
No. of customer orders		orders	0	s	0,0	h	
3. Prepare packing material							
No. of cartons		cartons	0	s	0,0	h	
No. of letters		letters	0	s	0,0	h	
4. Pack items							
No. of moves with items		moves					
No. of packages		packages	0	s	0,0	h	
5. Seal and add label							
No. of cartons with tape		cartons	0	s	0,0	h	
No. of cartons with plastic straps		cartons	0	s	0,0	h	
No. of letters		letters	0	s	0,0	h	
No. of cartons with label only		cartons	0	s	0,0	h	
6. Put package on conveyor belt or in tote							
No. of packages		packages	0	s	0,0	h	
7. Sort package on pallet							
No. of packages		packages	0	s	0,0	h	
8. Transport from mezzanine floor							
No. of pallets		pallets	0	s	0,0	h	
9. Wrap pallet in plastic							
Wrapping technique							
No. of pallets		pallets	0	s	0,0	h	
10. Load pallet on vehicle							
No. of pallets		pallets	0	s	0,0	h	
11. Additional inputs							
Additional inputs			0	s	0,0	h	
Total time packing			0	s	0,0	h	