CHALMERS

Analyzing warehouse operations in a 3PL company

Mapping of processes and identification of key time drivers

Master of Science Thesis in the Master Program Supply Chain Management

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Abstract

Warehouse operations in a 3PL company are often very specialized and customer unique. Thus, estimating the need for manual labor when designing new warehouse solutions can be a complex procedure. One of the main issues for Schenker Logistics when quoting future customers is to know the required blue-collar labor and how to distribute operators between inbound and outbound processes. The purpose of this Master's thesis is to create a calculation tool that describes different time drivers in warehouse operations and facilitates estimations of required manual labor at Schenker Logistics. To fulfill this aim, two main sources of data were needed. Firstly, observations for five different types of customers were performed in order to gain deep understanding about inbound and outbound processes, which allowed the development of customer specific process maps. These acted as foundation when determining relevant standard processes, activities and tasks necessary for further observations and time recordings. Secondly, time studies were performed for the predetermined elements and the collected data was analyzed to identify significant time drivers. The results were used to develop a calculation tool that considers different arrays of data and factors to calculate the required manual labor, given customer specific inputs. The calculation tool was later tested in order to assess its validity and calculate time allowances, which are described together with general recommendations of improvements in current warehouse solutions in the final part of the thesis.

Keywords: Process mapping, time measurement, warehouse operations, time drivers

Table of Contents

Preface

This Master's thesis was performed at Chalmers University of Technology as a final part of the Master's program Supply Chain Management. It was carried out at Schenker Logistics AB, in close collaborations with employees and supervisors at the headquarter and warehouses. The study has given us valuable insights in warehouse operations and how 3PL companies operate today.

There are certain people who have offered us great guidance and support throughout the study. We would like to direct our gratitude to them. Firstly, we would like to thank our tutor at Schenker Logistics, Nikolai Kolderup-Finstad, who has been a guiding star throughout this study. We would also like to thank Fredrik Bohlin at Solution Design, who has given us valuable and continuous feedback regarding our work.

We would also like to express our appreciations to all team-leaders and operators in the distribution centers at Landvetter and Torsvik. We would like to thank them for their participation during our time studies and for consistently providing valuable answers to our questions.

Finally, we would like to thank our tutor and examiner Ola Hultkrantz at Chalmers for your support and constructive criticism throughout the work.

List of abbreviations

ABC – Activity-based costing

CT – Control Tower

DB – Deutche Bahn

DC – Distribution center

FIFO –First-in-first-out

FTE – Full time employee

LIFO – Last-in-first-out

MOST – Maynard Operation Sequence Technique

MTM – Method and time measurement

PF&D – Personal, fatigue, and miscellaneous delay

PO – Purchase order

RFQ – Request for quotation

SKU – Stock keeping unit

SLL – Schenker Logistics Landvetter

SLOG – Schenker Logistics AB

TMU – Time measurement unit

WMS – Warehouse management system

VAS – Value adding service

VNA – Very narrow aisle

3PL – Third-party logistics

1 Introduction

This section will provide an introduction to the Master's thesis, starting with a general introduction of the logistics industry and a background to the issue. This is followed by a problem discussion and the purpose of this thesis. Finally, the outline of the thesis will be described.

1.1 Background

In today's global markets many manufacturing companies increasingly focus on their core competences and outsource other activities. The reasons behind the decision can be to reduce cost or increase customer service and revenues, by for instance reducing lead-times and increase flexibility and responsiveness. By outsourcing less strategic activities, where for instance the level of competitiveness relative to the suppliers are low, the company can get access to competence or resources not present internally today. (van Weele, 2010)

The trend of increased outsourcing creates situations where competition is present between different supply chains rather than between individual companies (Christopher, 2011; van Weele, 2010). Transportation and logistics are important parts of the supply chain and provide many opportunities to reduce costs and increase flexibility and responsiveness. A third-party logistics (3PL) provider is a company that offers service to its customers for part, or all, of their supply chain management functions (Kolderup-Finstad, 2012).

The competition in the 3PL market has increased the recent years and customers have become more demanding and less loyal to specific suppliers. This has created a situation where 3PL providers must offer customized services; while at the same time strive to reduce costs in order to gain competitive advantages. Furthermore, the customer base of 3PL companies often consists of actors within many different industries with varying needs and requirements. Therefore, the suppliers must be able to provide a broad set of solutions that suit the customer's particular environment. These services can for instance include complete distribution and warehouse solutions, inventory management, customer service center and additional value adding services (VAS).

This Master's thesis will focus on the transport and logistics industry and Schenker Logistics AB (SLOG), which is a fully owned subsidiary of DB Schenker. DB Schenker is a part of the Deutsche Bahn Group and is one of the largest transportation and logistics service provider in the world (a more detailed description about SLOG will be presented in section 4.1). In the late 2011, SLOG started operating in the newly build distribution center (DC) and headquarter in Landvetter in the outskirts of Gothenburg. Here, Schenker Logistic Landvetter (SLL) offer their customers complete logistic solutions and tailor-made warehouse designs, especially in the field of consumer and retail (Kolderup-Finstad, 2012). SLOG's ambition is to reduce the total costs of logistics for their customer, by offering high degrees of process efficiency and flexibility (Om DB Schenker, 2012). In order to achieve this, SLOG must work continuously with evaluating their current operations and processes.

1.2 Problem discussion

Every customer and solution at SLOG has their own specific characteristics when it comes to operation and process design. Working with many different types of solutions increases the complexity of the overall logistics operations in the warehouse and thus the need for efficient process management. Furthermore, many of the customers to SLOG often lack full understanding of their own need and requirements.

When quoting and designing solutions for new customers, one particular and very important task is to determine the amount of blue-collar labor needed to perform certain activities. The solution developers at SLOG estimate that about 50-60 percent of the total costs are related to manpower, which increases the importance of valid data during the design and tender procedure.

SLOG is currently using an Excel-based logistics tool developed by Schenker Logistics in Germany for estimations of required blue-collar labor. This calculation tools builds mainly on data from Warehouse Managing Systems (WMS) in other countries, where processes and systems are very different compared to the ones at SLOG. Thus, it can be difficult to obtain accurate and reliable outputs when applying the current model on the operations at Landvetter or other distributions centers in Sweden. As a result, the estimated need of manual labor, and thus the calculated customer profitability, can differ compared to the reality. In order to facilitate the quoting process and make it as accurate as possible, an efficient tool with an updated time database is needed, with data that reflects the processes and activities that exist at SLOG today.

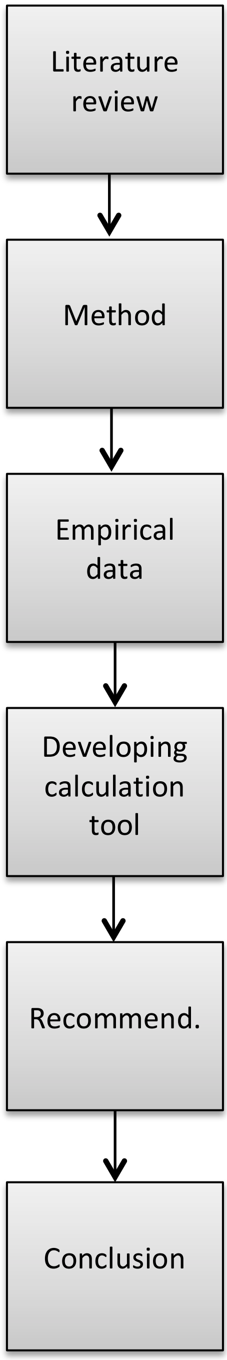
1.3 Purpose

The purpose of this Master’s thesis is to create a calculation tool that considers different time drivers in warehouse operations and facilitates estimations of required manual labor at SLOG. The aim is to gain deep understanding of different types of solutions and how the complexity and size of these can impact productivity. Furthermore, the processes of five different customers will be analyzed in order to find potential improvements.

In order to fulfill the purpose of the Master’s thesis, the following questions will be answered:

1. How are standard warehouse processes designed at SLOG?
2. Which activities drive time in these processes?
3. What factors (e.g. volume, level of pick, equipment, depth of pick etc.) affect productivity in the warehouse processes and to what extent?
4. How can time measurements be performed on customized operations?
5. How can collected data be used to develop a calculation tool that facilitates calculations of required blue-collar labor?
6. How can time allowances that consider different solution designs be estimated by using the developed calculation tool?

1.4 Thesis outline



Literature review - This chapter presents the theoretical framework relevant for the thesis. It will explain concepts such as processes, time measurements and warehouse activities.

Method - The method chapter describes the applied research approach and how the study was conducted. The chapter will briefly discuss the data collection, the development of the calculation tool and how the tool was validated.

Empirical data - This section contains detailed and specific information gathered from five different customers. It describes each customer's in- and outbound processes, which act as foundations for the analysis. Therefore, it is possible to disregard this section in order to avoid repetitions of concepts and activities. For each customer there is a process map that displays the different activities related to each process. In the beginning of the chapter there is also an introduction of SLOG and a general description of the in- and outbound processes at Landvetter.

Development of calculation tool - This section will describe in detail how the calculation tool was created. There are four main processes in the tool; reception, put away, picking and packing, where each process has a corresponding process map. These maps are simplified versions of the processes built on observations and discussions with chosen customers. This section also includes a detailed description of how the tool was validated and how the time allowances were determined. Finally, the quality of the calculation tool will be evaluated.

Recommendations - This section will provide some general recommendations for the current processes of the observed customers at SLL and comments on the appropriate use of the calculation model.

Conclusion - The final chapter summarizes the study and introduces some areas for future studies.

2 Literature review

This section will give an introduction to prior research and literature relevant for this thesis. It will provide a theoretical background for important concepts such as processes, time measurement and warehouse activities.

2.1 Processes

Managing processes in an efficient way is essential for the long-term survival of a company (Kalman, 2002). Many companies seek to reduce excess of any form that are costly and can be removed. A first step to achieve this is to understand what type of processes the company has and how they work.

2.1.1 Definitions

A process can be described as a set of linked activities that takes an input, adds value to it, and provides an output to an internal or external customer (Harrington, 1991). Davenport (1993) also stresses the importance of time and place when stating that a process has a beginning, an end and a structure for action. Another important component of a process is that the quality of its output can be monitored and measured, which can be used to regulate and improve the process (Conger, 2011).

Organizations often have between five to eight core business processes, which can be categorized as production or business processes, generic customer processes or product development processes (Kalman, 2002). Each core process (or macro process) can be divided into sub processes, which in turn consists of a number of activities. An activity can be divided further into tasks at micro level. Having a process approach to the organization is beneficial, since it brings discipline to the way work is done and helps increase reliability (Garvin, 1995).

2.1.2 Process mapping

Mapping processes enables representation and analysis of business processes and can be used to understand existing processes and to redesign them to improve business performance and customer satisfaction (Kalman, 2002; Klotz et al., 2008). It can be used to analyze tasks to show cross-functional relationships between organizational units and to see how activities interlink. A graphical representation can show the differences between how activities are suppose to be performed and how it works in reality. Klotz et al., (2008) emphasize the use of process mapping to increase transparency or process visibility in the organization, which means that everyone can be able to see and understand all important aspects and the status of an operation at all time.

Mapping processes can also increase learning, since it helps cross-functional units to understand their interdependent relationship with others and use that as a basis for improvements. Furthermore, the use of process mapping can simplify workflow, help reduce cycle times, improve quality, eliminate source of error, reduce costs by eliminating waste and increase job satisfaction and communication between units. (Kalman, 2002)

Kalman (2002) describes the seven steps of process mapping as follow:

1. Pre-mapping, e.g. identify the critical business issue or problem, select a process owner and set a measurable goal.
2. Construct a macro process map.
3. Identify bottlenecks and problems in the existing process.
4. Prioritize the bottlenecks and problems in the existing process.
5. Construct a micro-map of selected sub processes and identify the root causes of the problem.
6. Rebuild the map.
7. Develop action plans for management approval.

Conger (2011) also points out the need for thorough review of processes as a preparation for process mapping. This can be performed by interviewing all parties involved and collect relevant information, before developing the actual process description and maps.

2.1.3 Creating process maps

There are different types of visual mapping techniques that can be used when mapping processes and each method suits different situations. Block diagrams can be used in order to get an overview of the sequence of activities in a process, while the American National Standard Institute (ANSI) standard flowchart is used to display the decision steps and alternative process paths. Other examples are functional flowcharts that show how different organizational units interact; operations charts that map value adding and non-value adding steps; and so-called string diagrams that visualize the physical flow of work activities. (Kalman, 2002)

When developing generic process maps, several icons are used that represent different types of activities or data. Some common process mapping icons are displayed in Figure 1 below.

Symbol	Definition
Start	The start symbol represents the event or condition that starts the process.
Stop	The stop symbol represents the event or condition that ends the process.
→	The arrow represents the direction of the process. It has no relationship to the data, documents, applications etc.

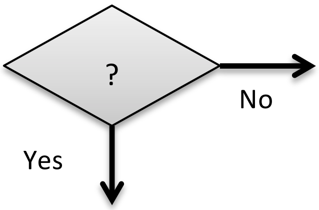
	The process symbol is used to describe an event, step or steps in the process.
	This symbol represents a logical decision or conditional processing step, e.g. by a yes-or-no question. A yes-answer will lead to a different event than for a no-answer

Figure 1. Common process maps icons (Conger, 2011)

Figure 2 shows an example of how the process maps icons can be used together in order to develop a process diagram. Short arrows and boxes of the same sizes are recommended to increase readability and consistency of the diagram. The texts used to describe the actions are preferably short, direct and only contains relevant information. (Conger, 2011)

Figure 2. Summary of a process diagram (Conger, 2011)

As a first stage of mapping a process, Conger (2011) recommends developing an outline of steps used for conducting the process and then evaluating the list to see which steps that can be consolidated in order to symbolize a generic process. When the list is complete and correct, a whiteboard and sticky notes representing each action can be used to create an initial map. This method makes it easy to move elements around and increases the readability. The process map is then drawn on a paper and the goal is that the understanding of the process and its steps should be so clear and detailed that anyone that draws it will develop the same map (Conger, 2011). Variations are more likely to occur if the map is longer than two pages or 80 icons, but the basic process should be the same.

When the map is established, it should be reviewed to validate its completeness and level of detail to make sure that everyone shares the same understanding of the process. If it is approved, a digital process map can be created using graphic applications and programs. This is later verified and approved by interviewees and the client. (Conger, 2011)

When using the map to improve existing processes, remapping of the process should be performed in order to simplify and remove unnecessary steps or activities that add little or no value. According to Kalman (2002) this should be performed more than once in order to make significant process improvement breakthroughs, and not only find the obvious redundancies and inefficiencies.

2.2 Time measurements

This section will introduce some principles and methods for time measurements and describe how time studies can be performed in order establish both elemental and overall time standards. Furthermore, the principle of time-driven activity-based costing and time drivers will be introduced.

2.2.1 Time studies and time standards

Zandin (2001) defines a time study as "a procedure used to measure the time required by a qualified operator working at a normal performance level to perform a given task in accordance with a specified method". Measurements are used to develop leveled or standard times that represents the time it takes for an average skilled operator to perform the task at a normal rate. There are several reasons for performing work measurements and the most common is to improve productivity and to produce reliable time standards that will facilitate the development of more efficient workplaces and methods.

Time standards can be characterized as engineered or non-engineered. Non-engineered standards are often based on for instance guestimates, historical data, self-reporting, stopwatch time studies or benchmark comparisons, and usually lack adequate documentation of the conditions of the work performed. Engineered standards are more accurate since they result from computer-based calculations based on a complete specification of work conditions. (Zandin, 1994)

Zandin (2001) emphasizes the importance of using time standards for successful management decisions, since they provide essential information for effective operations. High quality time standards can be applied in many different areas, e.g. scheduling, staffing, line balancing, performance reporting, budgeting, materials requirement planning, system stimulation, wage payment etc.

2.2.2 Methods for time measurement

Several methods are available to measure and categorize standard work of operations. According to Zandin (2001) standard times can be obtained in three different ways. The first option is estimation, where the operator makes a qualified guess of how long time the procedure normally takes. This can result in over- or underestimated times standards. The second alternative is to obtain values through time studies, work sampling and physiological work measurement (a more detailed description of stopwatch time studies will follow in the next section). The final option is to use predetermined time systems, where the work task is categorized into different elements and where one standard time represents one element and motion. Times for all the elements are added together in order to obtain a standard time for the activity. This system does not require any time studies but it is important to assign time values that are representative for the work.

The choice of time study method depends on the type of task and how detailed and accurate the time standards need to be. The more accurate analysis, the longer it will take to perform the measurements. One of the most commonly used predetermined systems is MTM-1 (Method and Time Measurement), which is used to analyze basic motions in manual operations. The method identifies and breaks out the different actions and assigns a predetermined time to each one of them. Besides the MTM-1 there are two additional versions of the system; MTM-2 and MTM-3, which differs somewhat concerning the level of accuracy. The MOST (Maynard Operation Sequence Technique) system is another predetermined work system. It focuses on the physical act of moving objects and it assumes that the work follows certain predetermined patterns. (Zandin, 2001)

2.2.3 Stopwatch time studies

According to Zandin (2001) the stopwatch time study is the most common way to measure work. A time study in practice usually includes both a time study and a method study, where the person performing the time study (the analyst) also observes how the activity is performed in order to find improvements. Zandin (2001) describes the steps of establishing a stopwatch time standard as displayed in Figure 3. It usually starts with a method study that emphasize the need to analyze, improve and standardize the method before performing the actual time study.

After establishing appropriate method and making sure that the operators are following this, the next phase of the study can begin. This consists of choosing appropriate tools, selecting operators and elements, performing, setting performance standards, recording times and calculating elemental times. The following sections will describe the most important parts of the stopwatch time study and how to create accurate time standards.

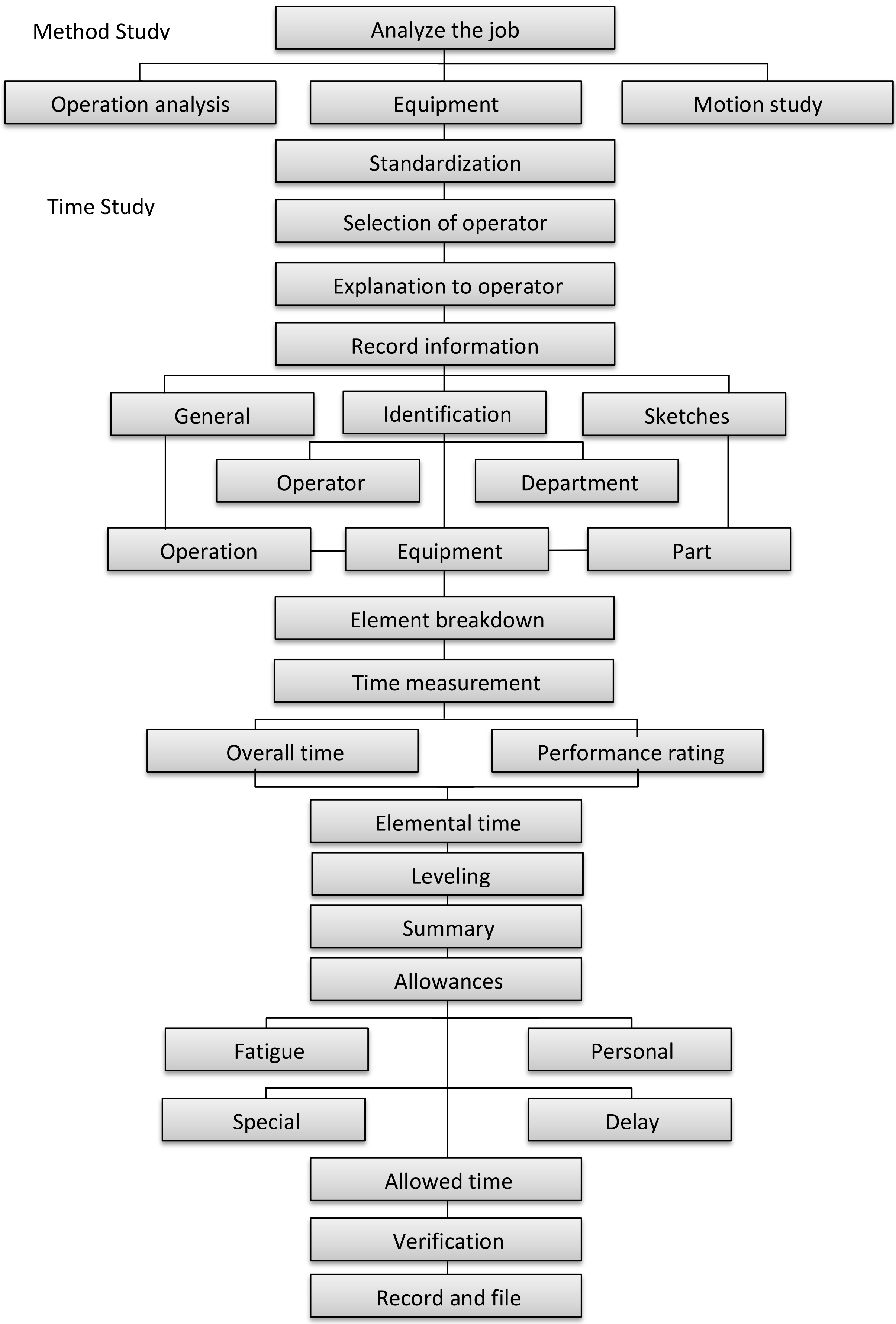


Figure 3. Establishing stopwatch time standards (Zandin, 2001)

2.2.3.1 Tools for performing a time study

A few essential tools such as a time study watch, clipboard with bracket, time study form, pencil and calculator or PC is recommended in order to perform a good time study. There are several types of stopwatches and the most common one is the decimal minute watch, which is often used in conjunction with MTM studies since these are using TMUs (time measurement units) set in decimal hours (Zandin, 2001).

The design of the time study form should be sufficient to cover two important categories of information. The first one provides a preliminary basis, such as the name of the product, operator, task, machine, date, observer etc. The second one explains the study, its elements, lists the observations and makes room for performance rating. Some additional space on the form might be useful for sketches of workplace layout or similar illustrations of the activity. The number of readings on a repetitive study form depends on the type of work, however ten observations is a common number. Low-volume and non-repetitive work might only require a few readings. The most important aspect of the study form is the recording of complete information that provides a clear picture of the study. (Zandin, 2001)

2.2.3.2 Selection of operators and elements

The time study procedure usually starts with the selection of operator. Zandin (2001) recommends not using an operator with greater working variance than 25 percent above or below 100 percent. The work methods and time study readings should be shown to the operators and team leaders in order to start an open discussion, prove the correctness of the time study and reduce any kind of resistance from the operators. It is also important that the analyst explains all the steps in the stopwatch procedure. Any uncertainties should be solved by asking related questions to the operator. Thus, an open two-way communication is important for the results of the time study.

The next step in the procedure is to select the elements, i.e. divide the specific activity or task into distinct and basic parts. An element can be regular (i.e. occur in every cycle), irregular (i.e. do not occur in every cycle but may occur in intervals) and foreign (e.g. errors and idle time that is not a standard part of the work). Elements can also be classified as constant and variable. (Zandin, 2001)

The length of the different elements depends on the activity, the level of detail and the aim of the time study. Thus, an element can be made of several fundamental motions or activities. Some of the advantages with dividing tasks into elements are that it is easier to rate the performance, identify non-productive work and develop standard time values for frequently recurring elements (Zandin, 2001). When defining the element it must have a clear beginning point, a specific work condition and an ending point. It should be as small as it is convenient to record, where time units of 0,003 to 0,004 minute are often considered as minimum limits for stopwatches. It is also preferable that the element only covers motions for one single object, that manual and machine times are kept separate and that irregular elements do not impact repetitive elements. Irregular and foreign elements can be either necessary or unnecessary parts of the work and should therefore be recorded and noted, but the unnecessary elements should not have any impact when calculating the standard time for the activity. (Zandin, 2001)

The amount of recordings needed can be obtained by charting element times and make sure that the collected values follow a normal distribution. If the observed values show flat or irregular scatters, it might be good to analyze the reason behind this and maybe change operator in order to get more valid and representable values. (Zandin, 2001).

2.2.3.3 Stopwatch timing methods

Timing the observations by stopwatch can be performed with two different methods. The first is cumulative timing, where the time is taken for the whole cycle and read at the end of each element without resetting the watch. The advantages of this method are that it is easy to learn, gives accurate time for the total performance and that the operators are more confident that all elements are included. The drawbacks are that variations, irregular elements and delays can confuse the results. It also requires more calculations since subtractions must be made for each element.

The other alternative is snapback timing, which means that the watch is reset to zero at the end of each element. The benefits with this method are that is good to use for irregular elements, it is not stalled by delays, there is no need for subtraction calculations and it is easier to read variations in the element times. However, this method is more prone to human error and the operators and supervisors are often less confident that all elements are included. (Zandin, 2001).

2.2.3.4 Setting performance standards

Observations do not always live up to the objective of a time standard, i.e. that they represent the required time it takes to accomplish a unit of work, following a specified method working at a desired performance pace (Zandin, 2001). Thus, it might be necessary to rate the performance of the operator and there are two concept associated with this. The first is dedicated effort, i.e. the required time for an operator following the method working with dedicated skills to finish the task. The second one is normal or average effort, which is often 20 percent less than dedicated effort. Zandin (2001) describes that working at normal or average effort, it takes about 25 percent more time to finish the activity than at a dedicated effort. The working conditions of the operator (e.g. incentives) must therefore be considered during the observations.

Determining which performance level to use depends on the management practices and concepts. Today, average efforts are the most common since it is easier to obtain a standard and that the times are considered as fair and reasonable. The analyst subtracts 20 percent from the average times to get the required time when using this approach. If instead dedicated efforts are observed, 25 percent are be added to the time values in order to get the average time. The benefits of the last alternative is that it is easier to convince supervisor and operator that the time standards are appropriate and even generous since 25 percent is used instead of 20 percent (Zandin (2001). The different approaches to setting performance levels are illustrated in Figure 4.

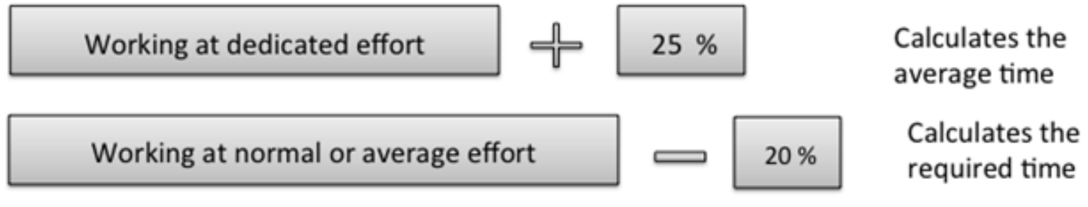


Figure 4. Illustration of how to set performance levels

Some companies also set the performance standards at the required time. The reason behind this is often that it is possible for the operators to perform the task at required time and that the difference in performance between the standard and the performance can be considered as waste, which in turn can be reduced by training, better scheduling and supervision. (Zandin, 2001)

2.2.3.5 Elemental calculations

When observations and recording is done the elemental times are gathered for analysis. The elemental average times are based on non-discarded observed elemental times over several different cycles and should be the most valid indicator of the typical observed time for the element. Sometimes, it may be beneficial to list minimum and maximum times when evaluating the timing and the leveling. If abnormally time values exist, these should be evaluated before determining the average value. (Zandin, 2001)

The analyst can also choose to consider the skill of the operator when calculating the average time. This is performed by adjusting the element average by the analyst's estimate of the operator's performance level. (Zandin, 2001).

2.2.4 Allowances on standard times

Allowances on leveled times refer to extra time allowed, beyond completion of the task itself. Zandin (2001) describes different managerial allowances that are added to the adjusted time per unit. These can be divided into personal, fatigue, and miscellaneous delay (PF&D). Personal time allowances includes for instance use of restroom, water breaks etc., while fatigue allowances try to compensate for physical or mental strain, noise level, heat etc. Other delays are necessary for long-term efficiency of operations or to compensate for time spent on pragmatically necessities, e.g. picking up dropped tools or consulting with supervisor. Some examples of elements in PF&D allowances are shown in Figure 5.

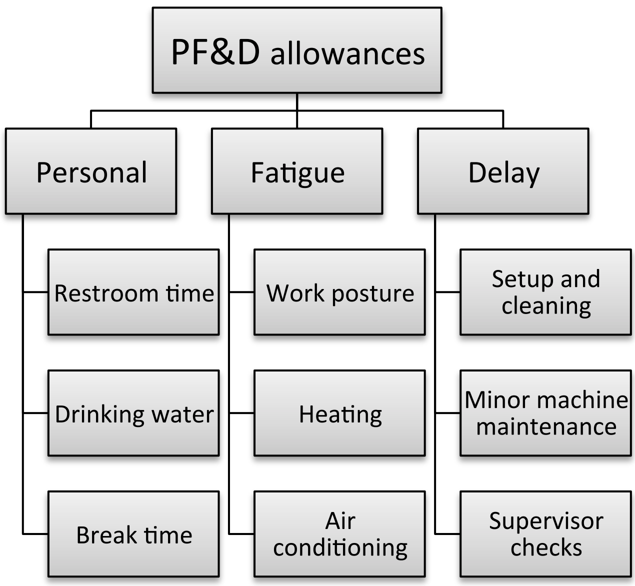


Figure 5. Illustration of different elements for PF&D allowances (ACC, 2012)

A rule of thumb for the last category is to add 3-5 percent for each type of delay, which provides a total range of 9 – 15 percent. However, the percentages should be based on past experience and be discussed before they are used. In similar way, Kaplan and Anderson (2004) state that often about 80-85 percent of the theoretical full capacity is used, which implies that around 15-20 percent of the time is spent on meetings, breaks, communication, training etc. Usually 20 percent difference is allowed for operators, while 15 percent downtime is acceptable for machines due to repair and maintenance.

Personal and miscellaneous allowances can be calculated relatively easily since they concern rest breaks or other interruptions during the activity, while fatigue allowances are more difficult to set since their percentages cannot be determined by observations. Zandin (2001) therefore recommends a combined percentage for all three aspects that is easier to verify than to verify the separate percentages.

2.2.5 Verification and validation

In order to use the developed time standards as a viable tool, the reasonableness of the study must first be validated. Mistakes in time studies often occur due to faulty methods or errors in the performance rating. Double-checking the results before the standards are set can mitigate these mistakes. Method errors are easy to find when reviewing the time study and comparing it with the method that the operator uses. If deviations exist, the analyst can discuss these with the supervisors or operators. (Zandin, 2001)

Verifying the performance rating is also rather simple and histograms can be used to see if the data follow a normal distribution curve and represents a proper leveling percentage for the study. If they do not have a normal distribution, the time values can be compared with similar observed times or a reference system. If there is a good match, the values can be assumed to be reasonable. (Zandin, 2001)

Validating the performance rating can be performed by for instance counting the number of items processed while observing the operator, then multiply this figure by the allowed time. The result is then divided by the elapsed time and the given percentage will represent the average performance of the operator. The correctness of the performance rating can then be assessed according to this figure. (Zandin, 2001)

Verification can also be made by showing the time standard elements for supervisors and operators, so that they can check the correctness of the values. It is usually easier to agree on individual elemental times than overall times. Making observation together with a supervisor, e.g. watching the operator finish a full cycle of elements, can help verify the standard times. (Zandin, 2001)

Zandin (2001) also recommends validating the standard times by following up on results and reasons why standards cannot be achieved, e.g. due to quality and material-handling problems. When the time standards are validated and approved, they are recorded and filed and available for reference in the future.

2.2.6 Time drivers and time-driven activity-based costing

Time standards can be used to define time drivers and perform activity-based costing (ABC) in order to design accurate cost systems in the organization. Traditional ABC is a way to use subjective estimations of the percentage of time spent on certain activities and assign resource expenses accordingly. Cost-driver rates (e.g. dollar per order) are used to allocate the department's costs based on customers' utilization of the department's activities (Kaplan and Anderson, 2004). However, using the traditional approach may lead to problem in large-scale operations where it is difficult to capture the complexity of the activities. If the model builds on time-driven approach instead, it simplifies the calculations and provides more accurate cost-drivers by allowing unit times to be estimated for even complex transactions (Kaplan and Anderson, 2004).

Everaert and Bruggeman (2007) describe time drivers as "variables (characteristics) that determine the time needed to perform an activity". Time drivers can have the form of either a continuous or discrete variable. A continuous variable can have any value between two points (e.g. weights or the distances), while a discrete variable takes the value from a finite countable set, such as number of orders or orders lines.

When performing a time-driven ABC, the model builds on the required time to perform a certain activity and the unit cost for supplying the resources, rather than using transaction drivers (e.g. number of orders). Applying this approach has been proven beneficial when designing cost models in situations with complex activities, e.g. in logistics and distribution companies with fast changing environments and where a certain activity does not require the same quantity of resources in every situation. (Everaert and Bruggeman, 2007)

One of the major advantages of using time-driven ABC is that calculations can consider multiple time drivers to determine the cost of an activity. The numbers of time drivers used is unlimited as long as they all come from the same pool of resources. The calculations can also account for interactions between different drivers, which is beneficial if one time driver depends on another factor, e.g. the time for processing an order might depend on the type of customer.

The developing of a time-driven ABC starts with estimating the cost per time unit of capacity and then the unit times of the activity. Estimating the time spent on certain activities can be performed by managers, where they assess the supplied capacity of resources as a percentage of the theoretical capacity (a rule of thumb is about 80-85 percent). Setting the required unit times for each activity can be performed by interviews or direct observations. By multiplying the two estimated input variables, the cost-driver rates can be calculated and used as a basis to assign costs to individual customers or start discussions with customers about pricing of new business. (Kaplan and Anderson, 2004)

The time equation displayed in Figure 6 shows how the required time for performing an activity can be calculated using discrete and indicator time drivers.

General Time Equation

$t_{jk} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_p X_p$ where:

t_{jk} = time required to perform event k of activity j

β_0 = constant amount of time for activity j, independent of the characteristics of event k

β_1 = time consumption for one unit of time driver 1 when X_2, X_3 …X_p are held constant

X_1 = time driver 1, X_2 = time driver 2 …X_p = time driver p

P = the number of time driver that determine the time needed to perform activity j

Figure 6. General time equation for time-driven ABC. (Everaert and Bruggeman, 2007)

2.3 Warehouse activities

This section describes the typical functions in a warehouse and introduces different storage devices and material handling equipment. The section ends with a description of different picking techniques and the advantages and disadvantages with different solutions.

2.3.1 Warehouse functions

According to Koster et al. (2006) the main warehouse activities include: receiving, transfer and put away, order picking/selection, accumulation/sortation, cross docking and shipping. Figure 7 depicts the typical warehouse functions and flows.

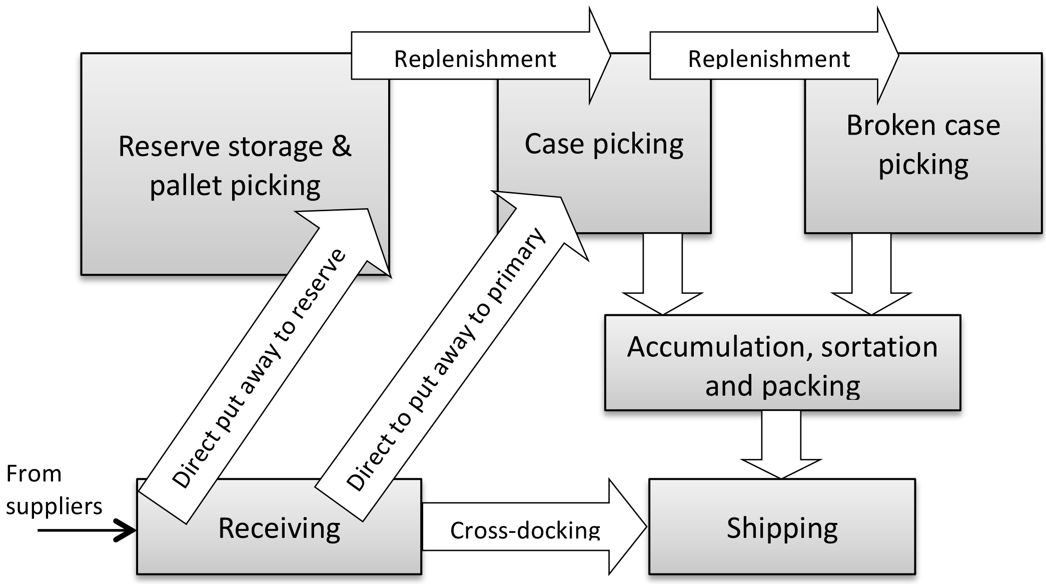


Figure 7. Illustration of typical warehouse functions and flows (Koster et al., 2006)

It is important to understand the relationships between the different processes in order to obtain the most optimal solution and hence minimizing the handling costs. The most important aspects of the warehouse functions are described below.

Reception

Reception activities consist of unloading items from the transport carrier. The incoming delivery is inspected to make sure that the quantity is correct and that the quality is sufficient. The inventory records are also updated with new information regarding the items. (Koster et al., 2006)

In some situations, the incoming goods pass through the warehouse without being put away in stock. This is referred to as cross docking, which is an activity where the incoming delivery is sorted directly on outgoing transport carriers. (Stephan and Boysen, 2011)

Put away and transfer

This process involves transportation of items to designated storage locations. It may also include repacking and physical transport from and to different areas in the warehouse. (Koster et al., 2006)

Picking

The order picking process is identified as the most labor intense activity in a warehouse and consequently the most costly. The costs related to order picking can be as much as 55 percent of the total warehouse operational expenses. The order picking process consists of activities such as; clustering and scheduling customer orders, releasing orders to the floor, picking of items from storage locations and then dispose of them. (Koster et al., 2006)

Customer orders consist of order lines and each individual order line represents a unique item or stock-keeping unit (SKU). Order lines can be divided based on the characteristics of product. The items can be picked in either a full pallet, case (carton) pick or broken case (unit) pick (see Figure 7). Usually all three options exists in a warehouse. Two basic picking variants can be distinguished: pick by article and pick by order. With pick by article, an operator picks multiple customer orders simultaneously whereas with pick by order, one customer order is processes at a time. There are many variants and customized solutions in between these two alternatives. (Koster et al., 2006)

Packing

When the picking process is finished the orders must be packed and sorted on the right unit load (e.g. pallet) before leaving the warehouse. (Koster et al., 2006)

2.3.2 Storage device

The most commonly used warehouse storage device is the so-called single-deep pallet rack (see Figure 8). As the name implies there is only one pallet stacked at each level and the pallets are retrieved with forklifts. For higher levels it is suitable to use a reach truck or a high-level order picker. The pallets on the bottom level are easily accessible with for instance a pallet jack. (Baudin, 2004)

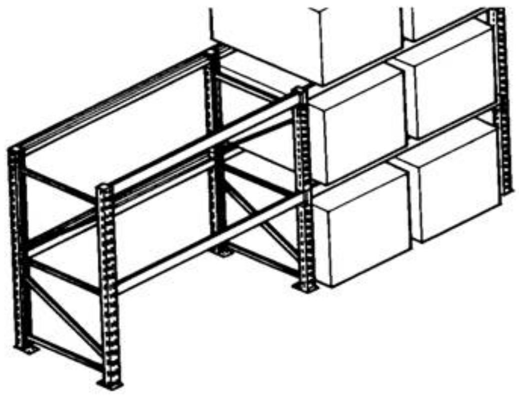


Figure 8. Single-deep pallet rack (MHI, 2013)

Double-deep racks or pushback racks are twice as deep as single-deep pallets racks and have two pallet slots at each location. Double deep racks increase the storage density but each SKU requires two dedicated slots in order to avoid moving the front-most pallet. The design follows the last-in-first-out retrieval (LIFO) and the solution requires a specific forklift with double-reach forks. Storage and retrieval require less labor than for single-deep racks. (Baudin, 2004)

Narrow aisle racking is a variation of single-deep racking but the aisle width is considerably smaller. The use of narrow aisle racking will increase the storage density but consequently decrease the number of forklifts that can operate in the area. Narrow aisles are designed to fit one specific forklift that must operate alone, resulting in a limited picking capacity. Hence, narrow aisles are not recommended for items that are retrieved frequently. (Baudin, 2004)

A design that follows the first–in-first-out (FIFO) retrieval is the flow racks (see Figure 9). The pallets are stacked on one side and retrieved on the other. In between there are flow racks that, with the help of gravity, move the pallets to the front-most position. The system enables stacking of pallets or cartons in multiple depths or lanes and requires the least labor of all the system mentioned. (Baudin, 2004)

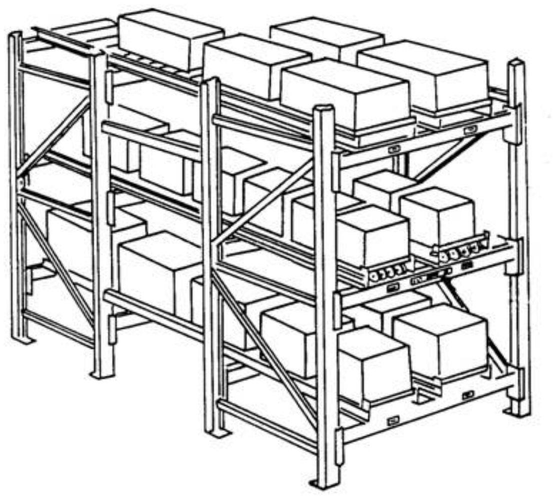


Figure 9. Flow through racks (MHI, 2013)

A simple and low investment stacking is the block stacking, where stackable pallets are placed directly on the floor. The problem however, is the man-hours required to rearrange pallets when retrieving pallets that eventually ends up in the middle. (Baudin, 2004)

Allocation

According to Baudin (2004) items can either have a dedicated slot or dynamically allocated slot. With dedicated slots all items have a specific location whereas items with dynamically allocated slots are positioned where there currently is an available slot – regardless of previous location. Allocation and storage devices can be a strategic important decision and rethinking the allocation strategy can save both time and reduce costs. Baudin (2004) suggests areas that should be reconsidered before allocating items, such as frequency of use, volume and destination.

2.3.3 Material handling equipment

Different kinds of material handling equipment are used to retrieve pallets, packages or items. A very simple and easy way to move and retrieve small items or boxes is by using a push chart or trolley. A push chart or trolley can be operated by anyone and are easily maneuvered in aisles. An example of a trolley with ladder can be seen in picture Figure 10. For heavier and bulky items or for items located at higher levels, it is more suitable to use a forklift. (Baudin, 2004)

Figure 10. Trolley with ladder and pallet jack (KM AB, 2013) and (RWsystems, 2010)

Forklifts are commonly used for in-plant transportation and there are many different variants. Depending on the type of goods and the location of goods, different forklifts are preferred. A pallet jack is preferable to use for short horizontal movements of pallets (see Figure 10). The advantage with a pallet jack is the low investments costs and the fact that the operator does not require any special training to operate it. An automated alternative to the pallet jack is the low lifter with platform, where the operator can stand on the platform during the transportation (Baudin, 2004)

A counterbalance forklift uses its battery or engine to counter the weight it is lifting. The forklift has a maximum load capacity of five tons and can lift up to eight meters. To fetch pallets from higher locations it is possible to use a reach truck (see Figure 11). A reach truck has a load capacity up to 2,5 tones and a lift height up to 12 meters. (Schenker AG A, 2012)

Figure 11. Counterbalanced forklift and reach truck (Atlet, 2013)

None of the mentioned trucks can however operate in narrow aisle racks where the width can be as narrow as 1,5-2 meters. For the narrow aisles a specific narrow aisle truck is required, which can lift up to 14 meters and has a load capacity of 2 tons (see Figure 12). The narrow aisle truck requires a certain guidance system, usually consisting of a rail or induction system. The forklift needs to lock its path in this guidance system before it can enter the aisles. (Schenker AG A, 2012)

Figure 12 Narrow aisle truck and low-level order picker (Atlet, 2013)

A high-level order picker is preferable to use when picking single items or boxes on different levels up to 14 meters. At lower levels, it is more suitable to use a low-level order picker. (Schenker AG A, 2012)

2.3.4 Picking procedures

There are many different picking methods and techniques used in order to identify and retrieve items and pallets. The different picking techniques can be divided in two major parts: goods-to-man or man-to-goods, which are displayed in Figure 13 below. (Schenker AG B, 2012)

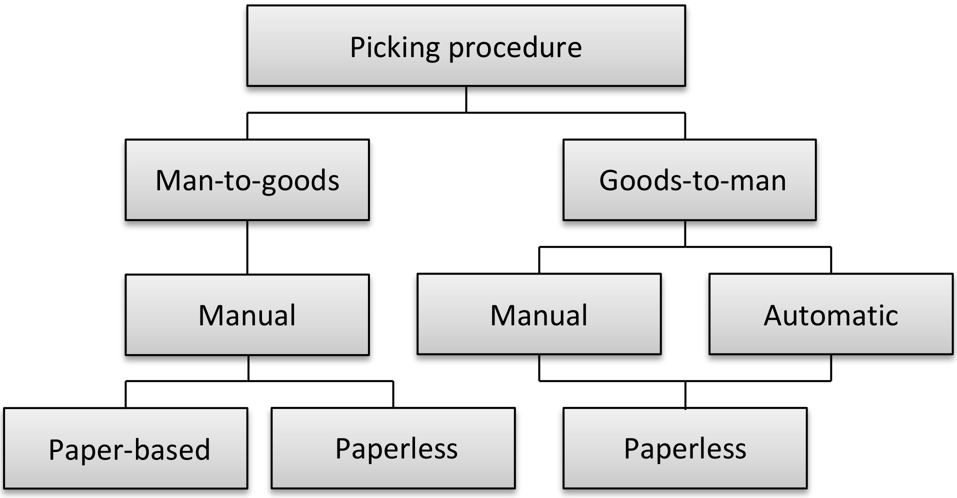


Figure 13. Picking procedures (Schenker AG B, 2012)

Man-to-goods

With the man-to-goods method, the items have to be picked manually from their storage locations by an operator. Usually the operator uses an order picking trolley or an order picking truck. Man-to-goods is suitable when there are many order lines per order and a small picking volume per order line. (Schenker AG B, 2012). Koster et al. (2006) denotes man-to-goods as a *picker-to-parts* system and stress that it is the most commonly used technique in warehouses.

Goods-to-man

With the goods-to-man method, items can be picked automatically from the shelf by an automatic system. The items are often placed at a conveyor belt where they are transported to awaiting operators. Goods-to-man is suitable when there are few order lines per order and when the picking volume per order line is high. (Schenker AG B, 2012)

Koster et al. (2006) refers to the system as *part-to-picker* and describes how automated storage retrieval systems with aisle-bound cranes are used to retrieve pallets or bins and place them at pick location. An operator picks the correct amount and if there are any remaining parts the pallet or bin is returned to its storage location.

Jonsson and Mattson (2009) state that it is beneficial to use automatic material handling systems for a frequent and standardized material flow. The conveyor belt is another kind of automatic material handling system, where the items are transported on a belt to the next process.

2.3.4.1 Picking techniques

The picking procedure can be either paper-based or paperless. With a paper-based picking technique the operator is aided by a list that contains necessary information regarding the order. There are three different paperless techniques and these are: pick-by-voice, pick-by-light and pick-by-scan. (Schenker AG B, 2012)

With pick by voice the operator wears a headset that receives information regarding the order lines, e.g. the location and the number of items to be picked. The operator confirms the picked amount by repeating the information in the headset and when this is done the next order line is initiated.

Pick-by-light is as the name implies a technique that uses lights to guide the operator. LED-lamps light up the correct item location and display the number of items the operator shall pick. The operator confirms the position and the picked amount by turning off the light. The action activates the next-coming lamp and the route continues.

With pick-by-scan the order is transferred wireless to a terminal that is either handheld or located on a forklift. A software program guides the operator through the picking procedures and notifies the operator about which items to pick and in what quantity. The shelves and/or the items are labeled with barcodes that the operator scans in order to confirm that the correct items are being retrieved.

The advantages with paper-based picking are the low investment- and implementation costs. Using paperless picking techniques, such as hand scanners, require investments in hardware and software as well as training of employees. A technical system is also exposed to the risk of technical failure and breakdowns, which might cause production stop. (Schenker AG B, 2012)

Paperless picking may on the other hand result in less picking related mistakes. Since the items or shelf locations must be confirmed, the risk of picking the wrong items is reduced. There is also flexibility in order management since all information is automatically updated and hence the lead-time for processing an order is reduced. The inventory levels are also updated to the latest figures, which help decrease the risk of stock-outs. The picking time might also be reduced. However, this should be evaluated before implementation in order to understand how the picking technique affects the processing time for that specific solution. A reduction in picking time will result in a more efficient picking and hence reduced the time spent on corresponding activities. (Schenker AG B, 2012)

3 Method

This section describes how the study was conducted in order to achieve the purpose of the thesis. It will illustrate the research design, data collection and analysis, as well as the development of the calculation tool. Finally, the quality of the study will be assessed.

3.1 Research design and approach

A research design acts as the foundation for collecting and analyzing data in a study. Bryman and Bell (2011) outline five different research designs: cross-sectional, longitudinal, case study, experimental and comparative design. A case study concerns a detailed and intense study of a single case with defined features and scope, where researchers strive to answer defined research questions (Gillham, 2010). Researchers using the other research designs are concerned with creating general research that is independent of time and place (Bryman and Bell, 2011). Since this thesis concerns the specific case of SLOG, it employs a case study design.

Additionally, this thesis also employs a cross-sectional design, which is defined as the collection of data on more than one case at a single point in time (Bryman and Bell, 2011). This is appropriate to apply for analysis of two or more variables to detect variations and patterns of associations. The study at SLOG concerns observations and comparisons of similar processes of several customers, and by gathering similar information from many different aspects during the same time period, the comparative design facilitates understanding of differences between customers and situations.

The advantage of the chosen research design is that it facilitates deep understanding of the warehouse operations in the unique case of SLOG. Comparing several customers and different processes in the warehouse facilitated the creation of a calculation tool that considers many types of factors, e.g. different systems, vehicles, picking techniques, etc. This would not have been possible if only one customer where in focus.

Furthermore, some aspects of the research design are of general nature, for instance the creation of process maps and the planning and performing of time measurements. The development of the calculation tool can also be described as rather general, even if it was adopted after the conditions of SLOG. Thus, the research design of this study can also be used when performing process mapping and time measurements in other industries, companies or operations.

One of the disadvantages of the research design is that the study focus solely on the processes in two of SLOG's warehouses and does not allow external comparison with other 3PL companies. Thus, it is uncertain if the results of the studies also apply in other settings than those of SLOG.

The research approach for this thesis consists of five distinct elements and these are illustrated in Figure 14.

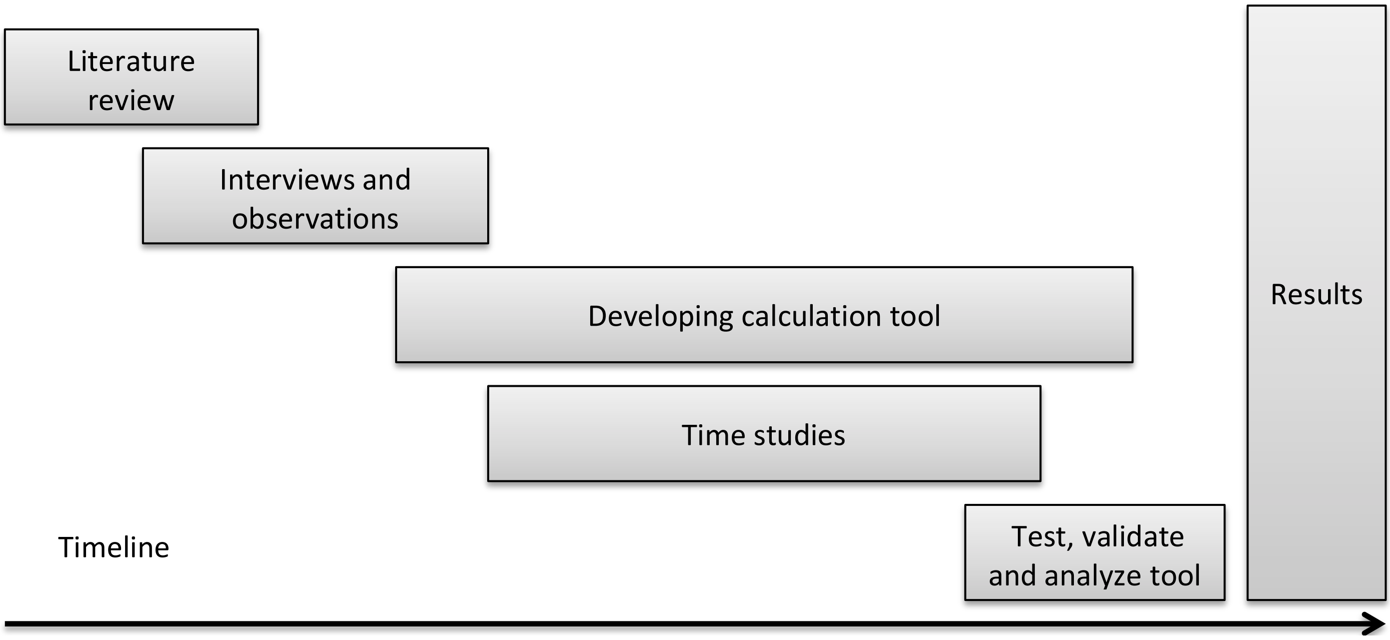


Figure 14. Research approach of the thesis

3.2 Data collection

The data in this thesis was collected in different settings. First, secondary data was gathered during the study mainly from databases, Internet and material provided by SLOG. Second, data was collected by conducting interviews with operators and making observations of processes for different customers in the warehouses. Third, quantitative data was gathered by performing recording and stopwatch time studies for each customer. Fourth, information was provided by open interviews with team leaders of the different customers and employees at the head office of SLOG. Finally, relevant data was provided at a later stage both by the IT Department and the tutor at SLOG in order to test and validate the final calculation tool.

According to Bryman and Bell (2011) data collection and empirical research can be divided into quantitative, qualitative and mixed research. This thesis employs a mixture of both quantitative and qualitative research. Qualitative data was used to gain deep understanding of the current situation and specific details about customer operations in order to create process maps and set standard processes. Quantitative data was then used to identify time drivers and to develop and test the calculation tool.

3.2.1 Literature review

A literature review was performed at an early stage in order to gain fundamental understanding of relevant subjects and prior researches in the field. Theoretical data was gathered from articles and books available in the databases of Chalmers Library, Google Scholar and Bocconi Library. The search for relevant literature was performed by the appropriate keywords related to process mapping, time study methods and warehouse design. Contacts at the Department of Transportation and Logistics of Chalmers also played important roles when providing unpublished articles and handbooks in the field of time studies, as well as contact information to representatives in the industry. The collection of relevant theory was an ongoing process and theory was added and withdrawn continuously during the study.

3.2.2 Interviews and observations

Six different customers were chosen for the study based on their characteristics in order to cover many different types of warehouse solutions, based on discussions with the tutor at SLOG. They are denoted as Customer A, B, C, D, E and F. A more detailed description of each customer and their processes can be found in section 4.2.

The warehouse operations of Customer E are characterized by their very bulky and heavy goods, and this customer was chosen to gain understanding of how these factors affect productivity, mainly in the packing process. Customer C was chosen due to its relatively small size concerning both manning and order volumes, in order to understand the connection between small-scale operations and productivity. The processes of the Customer D are characterized by picking of light-weighted goods in very narrow aisles with narrow aisle forklifts and the customer was mainly selected to provide required data for these specific alternatives the calculation tool. Customer A is a large-scale customer with a broad array of picking techniques and different process layouts, and was chosen due to its great variation and sources of data. The picking process and the size of Customer F reminds of Customer C, but Customer F has a very customized packing process and was therefore relevant in the initial phase of this study. The outbound processes of Customer B takes place on a mezzanine floor and this customer was chosen in order to understand how that particular solution design affects the productivity.

To gain a basic understanding of the different customers and their processes, two days were spent at each customer observing operators and asking open questions. There were no structured interview templates prepared for the observations, mostly due to the fact that the processes were unknown. However, at the first observation day at each customer the team-leaders gave an introduction of operations and shared information about the different warehouse zones, average number of workers, productivity goals etc. In general, one day was spent on observing inbound processes and one observing outbound processes. The aim was to gain understanding of warehouse operations in general and identify specific processes for the chosen customers.

The Customers A, B, C, D and F are all located in SLL, while Customer E is located in Torsvik, in the outskirts of Jönköping. Two days were spent on observations at Torsvik in order to get an overview of how heavy and bulky goods are handled.

When all observations were performed, the scope of the study was narrowed down with regard to the number of customers. Customer F was removed from the study due to its very customized packing process and its similarities with Customer C in other areas. Since the location of Customer E inhibited continuous collection of both quantitative and qualitative data, it was removed as an object for time studies and process mapping. However, the observations from the visit facilitated a general understanding of how bulkiness affects productivity.

At the end of each observation day, the information about the customers was written down and process maps were developed. The approach described by Kalman (2002) in section 2.1.2 for developing process maps acted as the foundation for the maps presented in this thesis. All maps are written according to the principles of ANSI standard flow charts. The first drafts of the maps were created on paper, and changes were made after further discussions between researchers and operators. Later, the maps were generated in the program Microsoft Visio, which is an application suitable for making flow charts. After collecting and summarizing all data, it was easier to detect if essential information was missing. If this was the case, additional information was gathered at a later stage. The developed process maps for each customer are displayed in the empirical section 4.2.

3.2.3 Time studies

A literature review concerning time studies acted as basis for planning and determining how the time recordings should be performed. Many of the mentioned time measurement methods such as MTM and MOST (see section 2.2.2) turned out to be too detailed for this study, since these methods are best applied to standardized and highly repetitive tasks with short cycles. However, theory regarding stopwatch time studies describe in section 2.2.3 was very helpful when designing the method and time study approach used for the purpose of this Master's thesis.

Before starting the collection of quantitative data, time study templates were created by using Microsoft Excel. The templates were designed to contain standard information independent of the type of observation made, e.g. name of study, operator, observer, date, etc., as well as additional information that characterized the specific activity. An example of a time study template used for observations can be viewed in Appendix A.

A large portion of time was spent on dividing the different processes into activities and defining the boundaries of each activity. In the initial phase of the time study design, detailed information about each element was noted in the time template and stored for later use. The information was systematically updated during the process of the study, since collection of new data came to affect the original versions.

One document containing several time templates was created for each process, i.e. reception, put away, picking and packing. Each document contained different numbers of sheets according to the number of subsections or activities required to complete the process. Hence, the document concerning the packing process had one sheet containing a time template for the activity "print a label", one sheet for "pack item", one for "seal packages" etc. By using the tool for sorting and filtering, information from several customers could be stored in the same sheet. This facilitated analyze and comparison of relevant data.

When the first drafts of the time templates were set, the quantitative data collection could start. Smartphones were used in the initial phase for recording the times for activities. These have a convenient stopwatch that facilitates cumulative timing, which was appropriate when recording repetitive activities with short cycles. Later on, handheld digital stopwatches were used when data from several activities had to be obtained simultaneously. The information was written down in the time study form, which was entered in the Excel-based time temples at a later stage.

The first time recordings acted as test studies since some of elemental boundaries had to be re-evaluated. It also became clear that some processes were not as standardized as first assumed and further breakdowns of different activities were necessary. The collected data could for instance show a greater spread for the same process than first anticipated, making it necessary to distinguish the activity between different factors. One example is that it takes longer time to prepare a carton than a letter; hence it is necessary to separate these activities.

In order to obtain standardized and reasonable data, the operators selected for this study were experienced and calm workers, all assumed to represent an average worker. The assumption is that all participated observers were working at average efforts, without any incentives or other factors affecting the outcome of their work. Before starting the recordings, the aim of the study was explained to the operators. It was clarified that the study sought only to obtain standardized values for difference processes and that the data should not be used for individual performance assessment. Furthermore, the operators were encouraged to work at normal effort and take no notice of the observers. Operators that did not want to participate in the study were excused.

All collected data from the time measurements was consolidated and analyzed in Excel where outliers and values with great deviations were evaluated and sometimes excluded from the data set. The number of obtained samples varied for each activity, where some activities only needed a few recordings in order to get valid time, while others required several days of observations. Most standard times are obtained by calculating the mean value of all valid observations, while others are expressed in different types of equations. This will be described further in the analysis in chapter 5.

3.2.3.1 Video recording

Some of the activities turned out to be difficult to measure solely by using the stopwatch approach and it was therefore necessary to record the events by camera in order to obtain reliable data. This was especially the case for the picking and packing processes due to the fact that several activities were performed very rapidly or were interlinked.

The recorded videos were played and analyzed in QuickTime Player. This facilitated identification and distinction of activities where boundaries were difficult to observe on sight. Usually it was enough to analyze the recording one time, however, some events required additional analysis to ensure the quality of the obtained data.

Both management and union approved the recordings before the studies began. It was also clarified to the operators involved that no external actor would have access to the recordings and that the material would be used only for the purpose of this study.

3.2.4 Other sources of data

Additional empirical data used for the description of the company (see section 4.1) was gathered from SLOG's website, as well through interviews with employees at the head office. Some quantitative data used as input for the calculation tool was collected by simulations in the warehouse, e.g. for calculation of average speed for walking with a trolley or typical times for picking items of different weights.

Finally, quantitative data concerning material handling equipment used by SLOG was provided by a contact person at Linde Material Handling AB. The provided data concerns six different types of forklifts and the selection was approved by the tutor at SLOG. The information obtained from Linde did not consider for instance additional time for turning around corners or the fact that it is not possible to operate at maximum speed in the aisles. Hence, the actual operating speed was substantially lower than the value given from Linde. Consequently, the obtained values were divided by a factor of four after consultation with the tutor at SLOG. Furthermore, the data is assumed to represent similar trucks from other brands.

3.3 Design of calculation tool

The first draft of the calculation tool was created after the observation stage, when all qualitative data was summarized and process maps for each customer were developed. The specific process maps were used in order to identify standard processes that would represent general processes and activities for inbound and outbound operations in the warehouse. By analyzing the customer specific process maps, it was possible to detect differences and similarities between different types of operations. It was important to distinguish between standard and customer specific activities, such as value adding services (VAS). Finally, the drafts of general process maps for reception, put away, picking and packing were created.

After developing the first drafts, a meeting with the tutor at SLOG was scheduled. During the meeting the foundation of the calculation tool was discussed, as well as relevant data inputs for different standard processes. Specific customer characteristics acted as a basis for discussion of how to divide the different sections, processes and activities.

The first draft of the calculation tool set the basis for the final version, with the two major sections for inbound and outbound flows. The inbound section contains one part for reception and one for put away, while the outbound has one for picking and one for packing (see Figure 15). Each part or process contains several standard activities required to complete the process. One activity that is present for all customers is replenishment. This activity was however excluded from the scope of this thesis and hence the calculation tool due to the limited time frame of the study. Other activities were excluded from the model for the same reason, for instance VAS and material replenishment at packing stations.

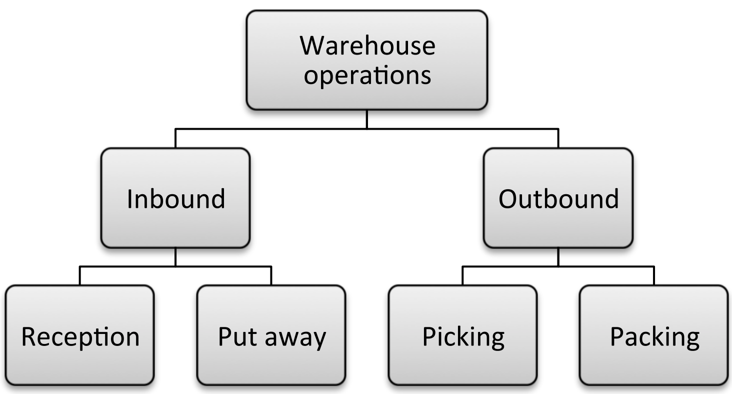


Figure 15. Main sections of the calculation tool and their processes

The necessary input data for each process of the calculation tool were thoroughly discussed in details during the design process. The difficulties were to identify factors that had the greatest effect on productivity, the so-called time drivers. Determining these was an on-going process, which lead to many redesigns of the tool during the study. Some values were more difficult to measure than others and some activities overlapped, which made it complex to define their boundaries. Continuous discussions, observations and interviews with relevant employees were made before all details were settled. Often the matters were discussed with the tutor at SLOG before any final decisions were made.

The calculation tool builds on collected data stated in man-hours, i.e. the amount of work performed by the average worker in one hour. This mean that in some cases where several operators have been performing an activity, the time is multiplied with the number of operators in order to get the value in man-hours. Thus, the assumption is the total time increases linearly with the number of operators.

After developing the tool, its validity was tested by using different type of input data, e.g. raw data from the WMS and production monitor and volumes from old Request for Quotations (RFQ). The results were compared with the reported working hours by the operators and invoiced hours for specific customers. In this way, time allowances in percentages considering personal, fatigue and other delays could be determined for different types of customers depending on their size and complexity.

3.4 Quality of study

The development of the calculation tool was a continuous process, which was highly dependent on the data collection and many redesigns were made during the study. There were frequent consultations with the tutor at SLOG regarding the creditability of the results. Furthermore, the observed times were also validated by discussion with responsible team leaders and operators.

In section 5.6 there is a detailed description of how the calculation tool was validated and finally there is a discussion regarding the quality of the study in section 5.7.

4 Empirical study

This section will present SLOG and the main logistics operations at the DC at Landvetter. This is followed by detailed descriptions and process maps of inbound and outbound processes for each of the observed customers. One of the customers is located in the DC in Torsvik and is only described briefly in this chapter. The customer specific data act as the basis for the processes described in the analysis, which results in similar and repetitive information between the different sections. Thus, section 4.2 can be disregarded if the reader does not seek to gain deep insights in customer specific processes.

4.1 Schenker Logistics AB

SLOG is one of the main 3PL providers in the Swedish market and the company has about 600 employees. The man focus for SLOG is warehouse operations but the company can also offer its customers transport services and hence complete logistics solutions. SLOG Sweden has a total warehousing space of 175 000 m^2 spread at five logistics centers in Sweden; Gothenburg, Jönköping, Nässjö, Stockholm. In addition, they are currently building a new center in Arendal, Gothenburg with an additional area of 25 000 m^2. (Kolderup-Finstad, 2012)

SLOG is a fully owned subsidiary of DB Schenker, which is a part of the Deutsche Bahn Group. DB Schenker is present in 130 countries and has 94 600 employees worldwide (DB Schenker profile, 2012). The organization in Sweden consists of 4000 employees with an annual turnover of 15 400 million SEK (Om DB Schenker, 2012).

4.1.1 Schenker Logistics Landvetter

In the late 2011, SLOG started operating in the newly built DC and headquarter in Landvetter outside Gothenburg. The warehouse in Landvetter has a capacity of 40 000 m^2 with a mezzanine floor of 8000 m^2. There is a clear ceiling height of 11,7 m and there are 25 gates that can be used to load and unload goods. SLL offer their customers complete logistic solutions and tailor-made processes, especially in the field of consumer/retail, technology, automotive and healthcare (Kolderup-Finstad, 2013). Currently, there are 13 customers in the warehouse.

4.1.1.1 Main operations in DC

The warehouse operations in the DC of SLL can be divided into inbound and outbound processes. Even though these are designed to fit the requirements of the different customers, the basis is similar for all solutions. Below, there is a short description of the main activities for inbound and outbound flow in the warehouse.

Inbound

The inbound process concerns all blue-collar activities required to receive incoming goods and make these available in stock for picking. In general, this involves receiving the truck driver or opening up the gate, unload the goods from the vehicle to a dedicated area where sorting, verification and controls are performed.

There are different ways to unload incoming goods. Goods loaded on pallets are easily unloaded by a forklift whereas separate cartons require other solutions. One solution is to unload each individual carton manually and place it on a pallet. A more time efficient way to unload is by using a portable conveyor belt, that is positioned in the container or truck. The cartons are unloaded by operators from the container or truck and placed on the belt, while operators at the other side of the conveyer load the carton on different pallets.

Each SKU or variant must be given a specific storage location, which is created by entering information in the WMS. Labels are printed and pasted on the items, which are then ready for put away in stock. The items are transported to their designated storage location by different means and the put away is confirmed either by hand scanners or lists.

Outbound

The outbound process involves all blue-collar activities necessary to collect and ship away orders to end customers. It starts when the orders are released and available for processing by an operator. Orders can be displayed either on lists or in hand scanners and the picking route is performed by different kind of forklifts or trolleys. The articles are placed at different levels for picking in shelves or racks in wide aisles, very narrow aisles, on open floor area or in low shelves at the mezzanine floor.

In general, the operator gets instructions of where to find the requested articles, transport the vehicle to the location, gets ready for picking, picks the required items and confirms the pick. When all orders or order lines are processed the operator returns to the outbound area where the goods are ready for packing. This process also involves confirming the order in the WMS and printing delivery labels and notes. Finished packages are sorted according to their destinations on pallets at the outbound area where they await pick up.

4.2 Customer descriptions and process maps

This section describes the different processes for each of the five customers selected for this study. Each subsection starts with a general description of the customer and its characteristics. What follows is a detailed description of the inbound and outbound processes. There are also illustrations of process maps and typical time distributions for the different activities for each customer. The exception is Customer E, which is only described briefly in order to gain an insight in that typical warehouse solution.

4.2.1 Customer A

Customer A is one of the larger customers of SLL considering the number of blue-collar workers and size of operations. The warehouse operations are divided into inbound and outbound processes, where each process has a team of workers and one or several team leaders. The teams operate rather independently from each other and have separate areas in the DC. The storage area can be divided into 11 different zones according to the product characteristics and picking procedures. The zones are:

1. Flow racks
2. Level 1 & 2 pallet racks
3. Level 3 and up pallet racks
4. Pallet racks for Torsvik (currently not in use)
5. Sealed cartons from pallet racks

6. Bulky and heavy goods
7. Fictitious storage for obsolete items
8. Customized orders for companies and associations
9. Narrow aisles
10. Pallet racks for shoes
11. Open floor area

Picking of bulky goods, shoes, articles from flow racks and open floor have distinct areas in the DC, while items from the zones 2, 3 and 5 can be picked from the same wide aisles. Zone 9 consists of less frequently picked items placed in very narrow aisles, without any buffer locations. These articles are often on the way to be phased out and have dynamically allocated positions. Orders for items in zone 8 are rather unusual and are therefore handled by the team leader. Zone 11 consists of fast moving items that are dynamically allocated on open floor locations. These products are typically subjects of marketing campaigns or markdowns at the retailers.

4.2.1.1 Reception

The inbound team is responsible for all inbound activities, i.e. unloading of vehicles, controls and sorting of goods, enter order information in the system, create storage location and put away in stock. Deliveries to Customer A arrive mostly during the day and if there are any delays, the evening's shifts picking-operators can unload the trucks.

Depending on season and number of incoming orders the workload and schedule look different every day. The operators have a schedule on a bulletin where the incoming orders for the day are displayed. It also contains delivery specific information such as the type of vehicle, number of cartons and type of loading. For instance, a FCL truck has to be unloaded within one hour. In other cases, the driver leaves the container during the night and collects an empty one, which means that the operators have the entire day to finish the unloading. SLL has in general 24 hours to finish the inbound process. Prior unloading, the operators look at the unloading list and prepare a plan for how to sort the cartons.

SLL receive deliveries by both truck and container. Trucks often carry pallets that are either single or double stacked, while containers in general consist of separate cartons that are placed, sorted or unsorted, directly on the container floor. The unloading process is less time-consuming when the boxes are placed on pallets since each pallet can be unloaded by a forklift, e.g. a pallet jack or a low lifter. When cartons are placed on the container floor, the operators must process these one by one. SLL can unload a container by placing cartons on a so-called Long John (a portable conveyor belt, see Figure 16) or on pallets on the ground inside the container. When using pallets, the operators fill these with goods and replace them with new ones when they are full.

Using a Long John does in general require more operators than if the unloading is performed completely manually, but according to the operators and team leaders it is often more time efficient. Cartons can easily be transported out from the container with the conveyer belt and normally there are one or two operators working inside the container by placing cartons on the belt. There are four operators at the end of the belt that identify, sort and place cartons on different pallets. One or two other operators operate on low lifters and transport full pallets to the sorting area.

Figure 16. Portable conveyor belt "Long John" (IC, 2013)

Unloading containers is a time-consuming activity and the complexity increases with the number of cartons and SKUs or variants. Besides, the cartons often have labels with vague information and bad handwriting, resulting in difficulties to read information regarding the content. Each pallet should only contain one variant, since the items will be placed in a specific storage location. The operators can either do the sorting during the unloading process or later at the sorting area. The latter case is much more time-consuming and the first alternative is therefore preferred.

When the goods are placed at the sorting area, the operators perform verification and quality controls. Unsorted cartons are sorted on pallets and mixed cartons containing several different variants are opened and the contents are split into new cartons. When all sorting is done, one or two operators are responsible for the quantity verification, i.e. check that the amount of pieces for each variant is the same as the information on the unloading list. After this, volume measurements are performed for new articles or in cases where relevant information is lacking in the system. The volumes are obtained by measuring the sides of the cartons, calculating the volumes for the whole carton and dividing it with the number of items inside. This information is later used for generating appropriate sizes of load carriers in the picking process.

During the product control, the quality as well as the article number and amount of pieces are checked for defects. If any deviations occur, these are reported to responsible coordinator at the Control Tower (CT), who in turn reports it to Customer A. A rule of thumb is to inspect around 10 percent of all the cartons or at least one box per variant on the order.

When the verification and volume control in done, the operator enters the information in the WMS and prints a label for each pallet. The activity starts when the operator enters the purchase order number in the system to get information about the items on the delivery. The operator has to process each variant separately in order to allocate appropriate storage location. Labels are then printed and brought to the sorting area where they are pasted on corresponding item.

If volume data for articles have been collected, these also need to be entered in the WMS. The operator can choose to do this while the labels are created or at later occasion. Finally, the delivery can be reported and picking orders can be placed for the articles.

Figure 17 illustrates a typical time distribution between the different activities performed in the reception process. The chart is based on data extracted from a RFQ, set on a weekly basis.

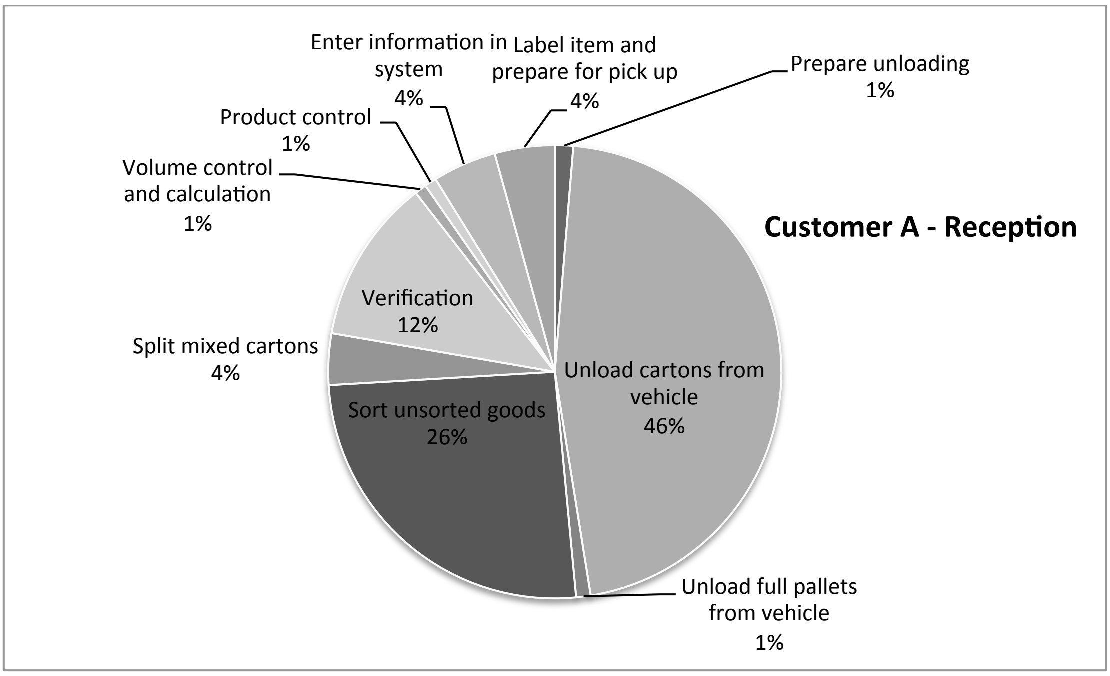


Figure 17. Time spent on reception activities for Customer A

4.2.1.2 Put away

When the items have been labeled, they are ready for put away in the different zones. Usually there is one operator responsible for this task, which is performed by a reach truck and a hand scanner. The operator positions the forklift to the pallet and scans the label to get the storage location. After transport to designated location, the operator leaves the item and confirms the put away by scanning the shelf label or entering a check figure in the hand scanner. The operator returns to the sorting area to collect a new pallet if there are more to process.

Figure 18 illustrates a typical time distribution between the different activities performed in the put away process. The chart is based on data extracted from a RFQ, set on a weekly basis.

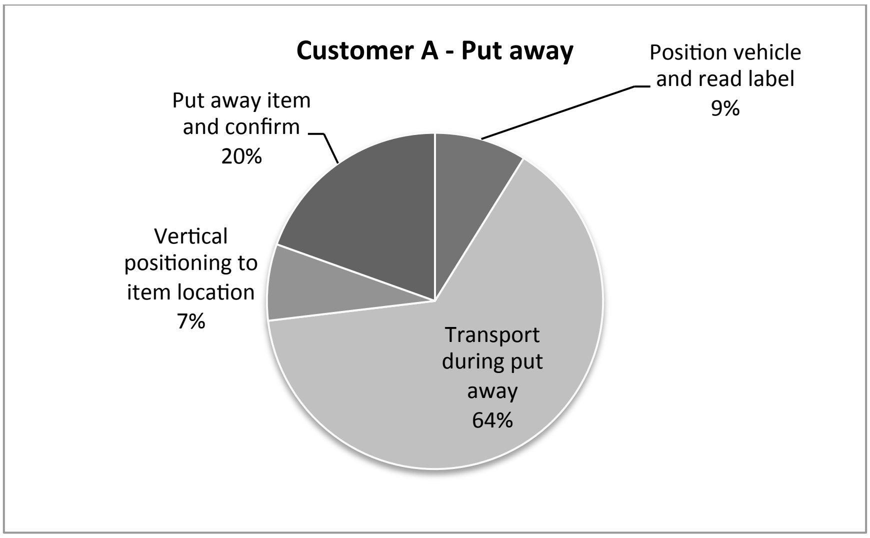


Figure 18. Time spent on put away activities for Customer A

The inbound process consisting of both reception and put away for Customer A are displayed in the process map below (see Figure 19).

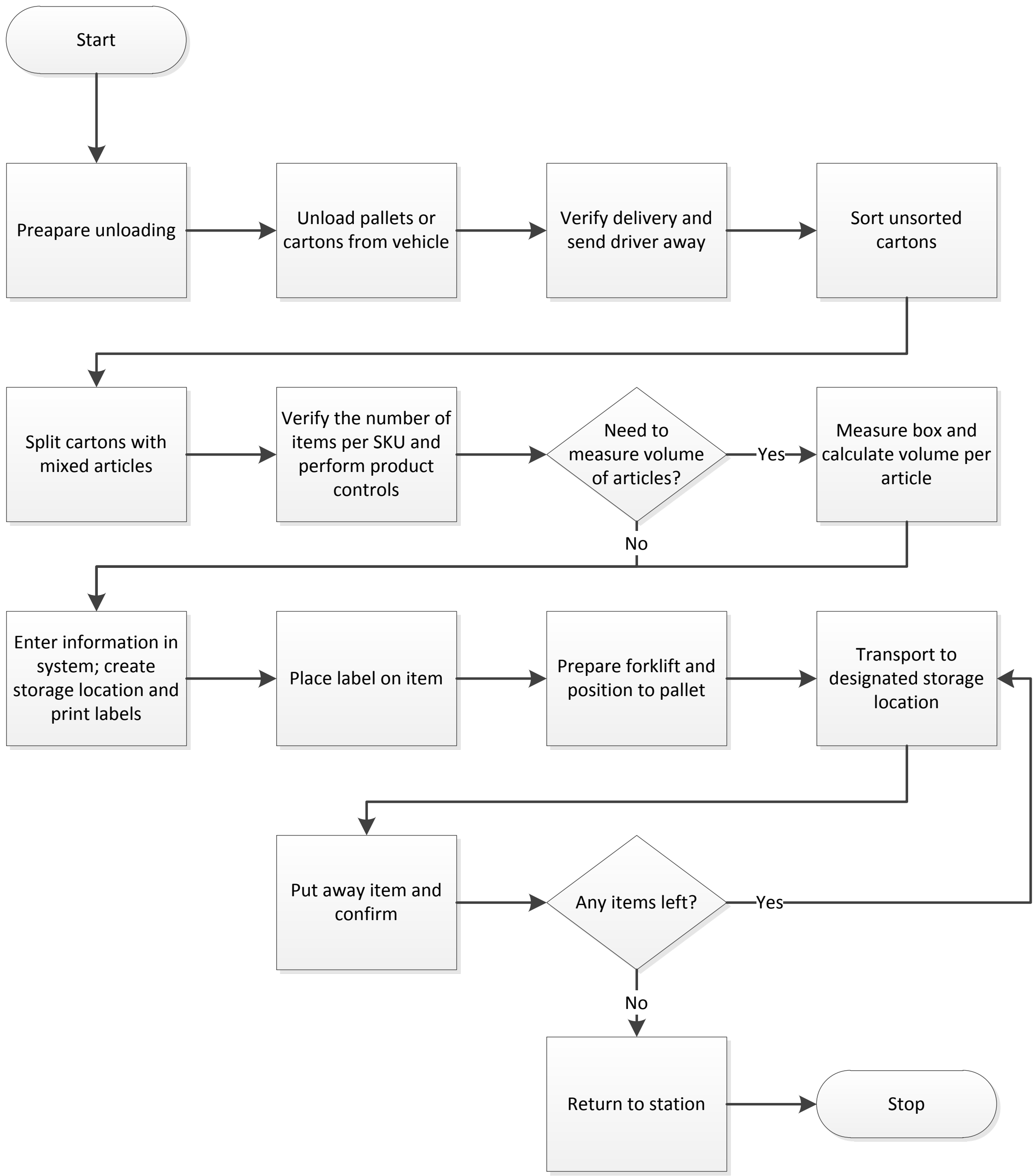


Figure 19. The inbound process for Customer A

4.2.1.3 Picking

Since the picking process for Customer A looks different depending on the warehouse zones, this section will give descriptions of the different zones in order to give an overview of the outbound activities for this customer.

Bulky goods

The zone for bulky goods is the only one where the operator is responsible for prioritizing and determining the order routes manually. The picking routes are performed without scanners and usually there are one to three operators working in this zone depending on the workload. The articles are heavy or of irregular shape, e.g. kettle bells, skies and bars, which make the picking process somewhat different from the other zones. Each order usually consists of one or two order lines and the operator can select how many orders to process. A rule of thumb is to pick between 10 – 15 lines per route.

The picking procedure starts when the operator prints the picking lists from the system and determines the route by sorting the orders according to their storage locations. The operator prepares the forklift and looks at the picking list to obtain the locations of the articles, which are indicated by handwritten marks on the floor. When the operator arrives at the location, the article number is controlled before the items are placed on the pallet attached to the forklift and the pick is confirmed

The picks are performed at low heights, from floor level up to level three. Some items are also placed in pallets at high-level buffer locations. At low level the items are stored in either pallets placed directly on the floor and on top of each other, or in low-level racks. The most time-consuming part of the picking process is to open up boxes, climb up to higher levels and handle bulky or long items such as skies and bars.

At the end of the picking route the operator confirms the picking route in the WMS. A scanner connected to a computer is used to read the picking list and receive the order information. Each order is processed separately and delivery labels are printed. If an order line requires several packages, it must be split by creating an additional load carrier in the system.

The operator usually starts packing loose items that require plastic wrapping, which often needs more processing than cartons. The package is sealed with plastic and a label is added before the package is placed on either a pallet or in a cage where it awaits pick up. Many of the other articles, e.g. kettle bells, are already packed in boxes and only require a label.

Flow racks

The picking process in the zone with flow racks is characterized by multi-picks of many small and loose items such as clothes, hats, socks etc. A trolley on wheels is used to collect items in flow racks at five levels and in standard wide aisles. The route is performed with hand scanners and the team leaders release orders to the operators ready to be processed.

The operator starts the picking process by confirming an order in the hand scanner and printing delivery labels by scanning a barcode on a printer at the station. A trolley with required amount of boxes and labels is prepared. Maximum 12 boxes that corresponds 12 different orders can be used for each route. The computer calculates the optimal picking route and displays information regarding location, amount of articles to pick etc. in the hand scanner. Arriving at the location, the operator scans the barcode on the shelves, makes a manual check of the article number, puts it in the right carton and confirms the pick by scanning the delivery label on the box. The hand scanner then displays the location for the next pick. When all items are picked the operator returns with the trolley to the packing station and confirms the order in the hand scanner. The cartons are placed at the packing station where they await sealing by other operators.

If a location is empty, the operator can use the hand scanner to order a refill. The replenishment orders are handled by another operator, responsible for all replenishments from buffer to pick location for Customer A. All buffers in the flow rack zone are placed over the corresponding flow rack in order to minimize the transport distance. The picking operator must wait for replenishment before completing the order. Other time-consuming factors are picking large amounts of the items and collect items from higher levels, when the operator must climb on the trolley.

Picking of shoes

The picking process of shoes is performed with a forklift in standard wide aisles at two levels, with buffers on higher heights. The aisles have one-way directions in order to avoid congestion. The WMS uses the dimensions of the shoeboxes to calculate the amount of boxes required for each order route. The operator uses the hand scanner to initiate the order and print labels, and then picks the items in similar ways as when picking from flow racks.

Picking of cartons

Picking cartons is rather simple compared with the other zones since the boxes do not require any packing. The operator prints the delivery labels and collects the cartons manually by forklift, adds labels and places the cartons on a pallet at the outbound area.

Picking in other zones

The picking procedures for the other zones are pretty similar to picking of shoes. They are performed mainly at two or three levels in wide aisles by order pickers and hand scanners.

Figure 20 illustrates a typical time distribution between the different activities performed in the picking process. The chart is based on data extracted from a RFQ, set on a weekly basis and is assumed to apply to mainly picking of shoes.

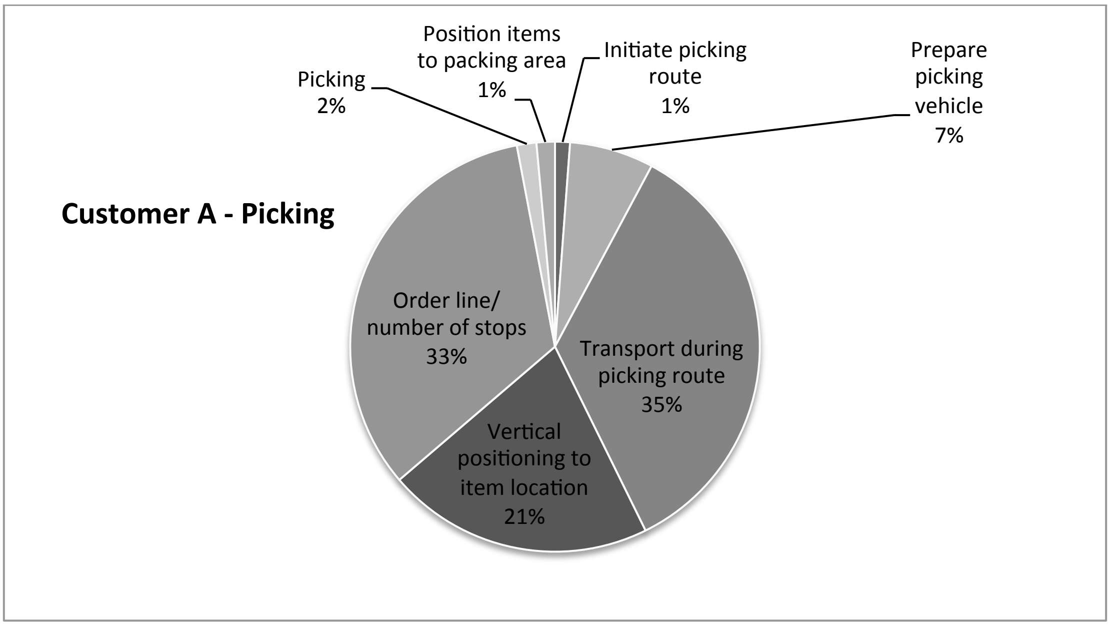


Figure 20. Time spent on picking activities for Customer A

4.2.1.4 Packing

All picking routes ends when the boxes are placed at the packing station; the only exception is bulky goods or already sealed cartons. The operator that picks the order has to make sure that is it easy to seal the package to avoid repacking. Usually there are one or two operators responsible for sealing cartons and placing them on pallets at the outbound area. All delivery information is available on the label and the operator seals the package by red or brown tape depending on the type of order. The pallets are placed at the outbound area where they await pick up.

Figure 21 illustrates a typical time distribution between the different activities performed in the packing process. The chart is based on data extracted from a RFQ, set on a weekly basis and does not consider bulky items.

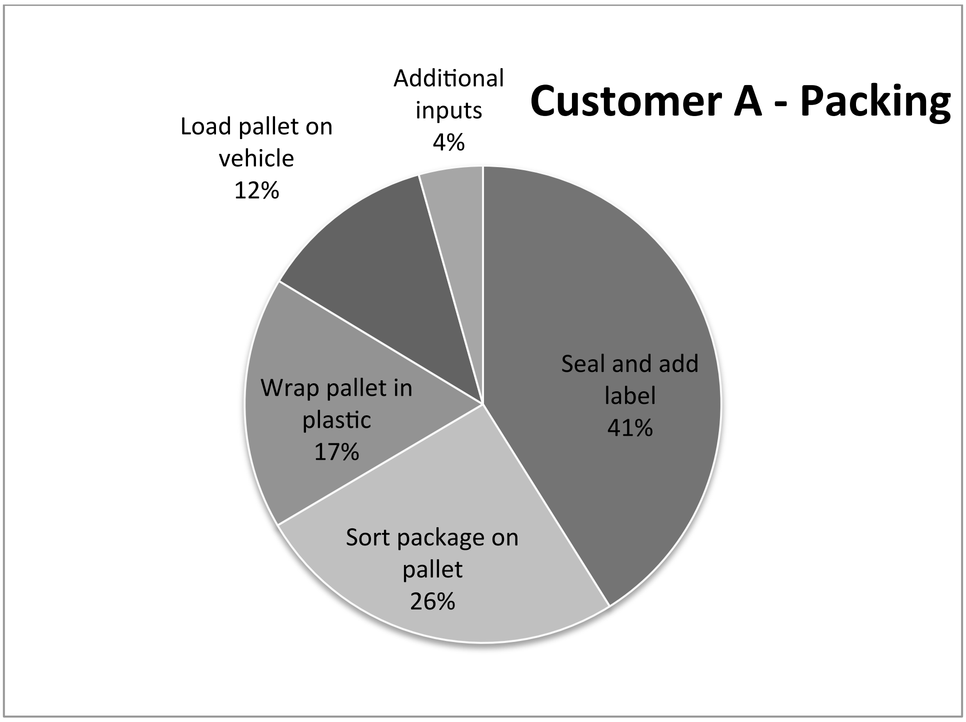


Figure 21. Time spent on packing activities for Customer A

The outbound process that consists of both picking and packing for Customer A can be seen in Figure 22 below.

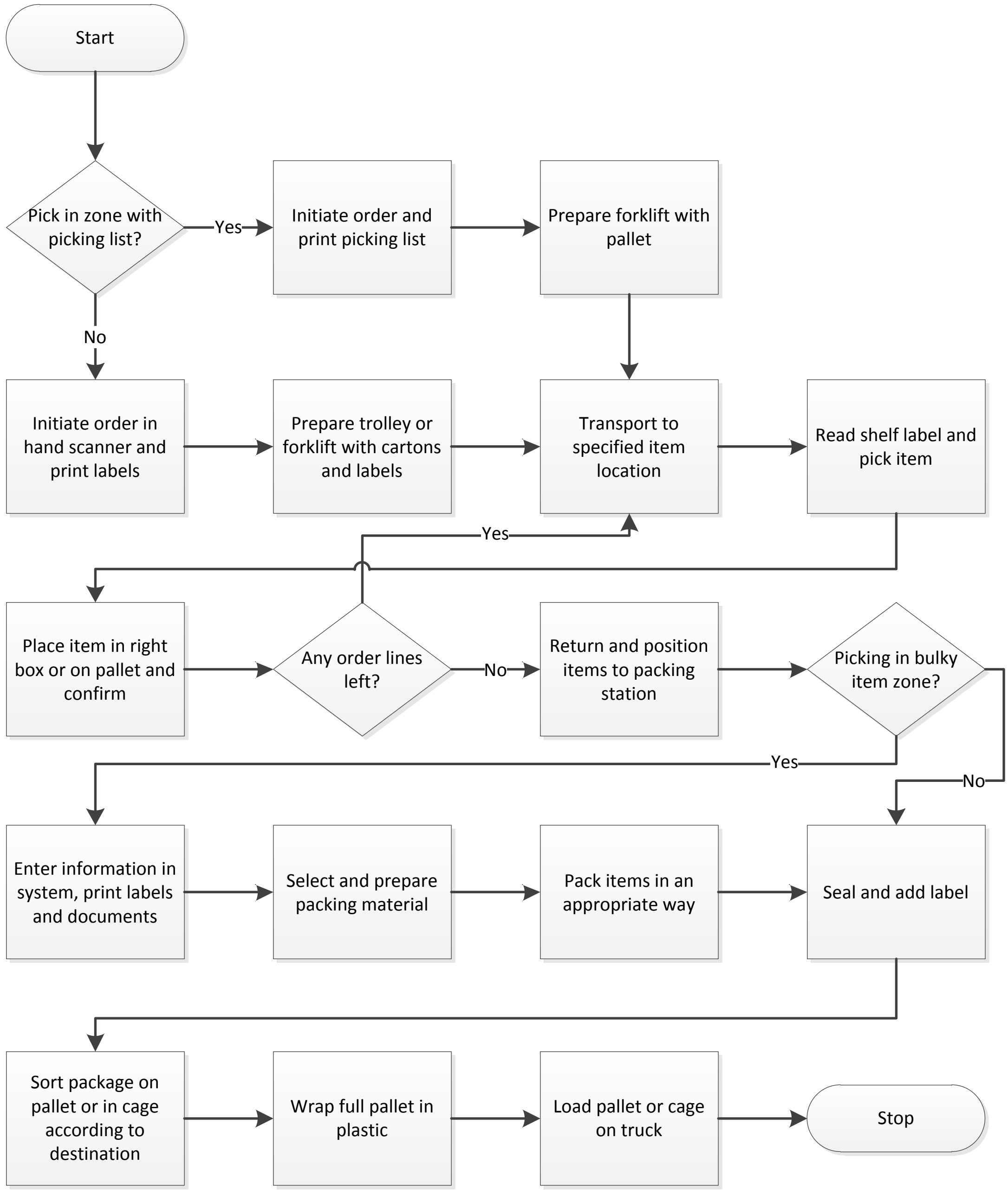


Figure 22. The outbound process for Customer A

4.2.2 Customer B

Customer B is supplier of professional wear and offers both standardized and customized products to customers. The warehouse operations for Customer B at SLL can be divided into inbound, outbound and production support. Production support handles claims, stock replenishments, system errors etc. and the time spent on these activities is considered as VAS. The storage area for Customer B is placed on the mezzanine floor, where small and lightweight articles are picked piecewise in low shelves at seven levels. There is also an area with three aisles for products on hangers (such as suits), picked at three levels. Larger items that do not fit in the shelves or on hangers are placed either on pallets along the side or on an open floor area at the end of the mezzanine. Since the aisles are narrow and the floor rather sensitive for pressure compared to the ground floor, the operators use trolleys and not forklifts for picking. However, a pallet jack is used for some of the transportation in the put away process.

SLL strive to place frequently picked items at levels at lower levels in order to minimize unnecessary climbing and movement and apply dynamically allocation of articles.

The area on the mezzanine floor is divided into three different zones. The first one contains professional wears to customers that require extra safekeeping, e.g. security services companies. These articles are more prone to theft and are therefore placed in shelves surrounded by a cage. The second zone consists of mixed articles that are picked frequently. Finally, the last zone mainly contains products for one large customer, but can also hold some additional articles.

SLL has buffer locations for Customer B in four very narrow aisles on the ground floor, with storing capacity up to 22 levels. Three of these aisles are used for pallet racking, while the rest is shelf locations for parcels.

4.2.2.1 Reception

Inbound deliveries to Customer B can arrive in different ways; as containers with loose cartons, separate parcels by courier and by truck where the goods are positioned on pallets. The vehicles are unloaded and the pallets are placed at the inbound area and all goods must be processed and reported into the system within 24 hours, if they do not require any processing for VAS. The operators have a list of deliveries and the team leader determines the prioritizing order.

Sorting of unsorted cartons are preferable done during unloading. A rule of thumb is to use purchase order number as a main reference point, and later sort after individual SKU numbers before the delivery can be verified and entered in the WMS. If any mixed cartons exist, these are opened and sorted according to SKU.

Quality and products controls must be performed for each delivery regarding article number, color and size. A guideline is to control at least three packages if the delivery contains more than 500 cartons. The operators must also measure the level of moisture in the fabrics and report this if exceeds 15 percent. Some suppliers to Customer B require additional processing for VAS. This is the case for deliveries from Portugal where 100 percent of all cartons and articles most be controlled.

After sorting and controls, the amount of articles per variant is verified and reported in the system. The operator finds the delivery number at the DB Schenker's client by entering the purchase number. The delivery number is used as the order number in the system to report the incoming goods and make them visible for the CT. The operator logs the purchase number, delivery number, number of packages, arrival date, number of repacks, time spent on repacking, moisture level, deviations etc. If one delivery consists of several deviations, it must be reported. The process is performed for each purchase order. As soon as the information is entered in the system, the articles can be ordered for picking. In most cases the operator reports after finishing each purchase order, but if the delivery consists of many orders and goods, the operator usually waits until all pallets are controlled.

The operator selects where to place the articles by choosing appropriate storage location in the WMS. The operator ends the process by printing labels with article information and storage position. The label is either placed on a full pallet or on a separate carton. Separate cartons are placed on pallets at the inbound area where they await transport either to the buffer area on the ground floor, or directly to pick location on the mezzanine floor.

Figure 23 illustrates a typical time distribution between the different activities performed in the reception process. The chart is based on data extracted from a RFQ, set on a yearly basis.

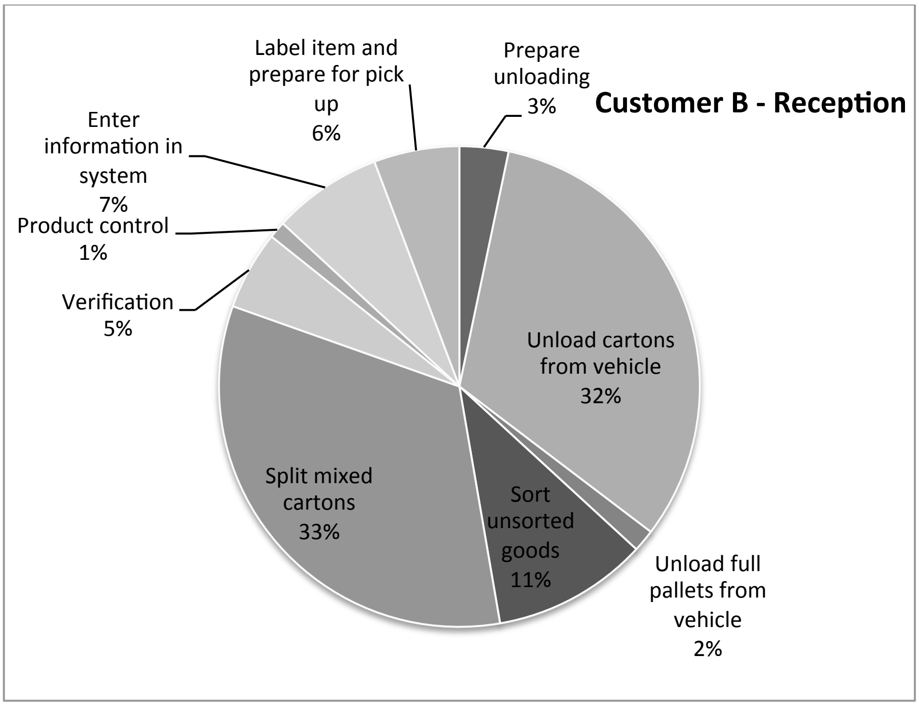


Figure 23. Time spent on reception activities for Customer B

4.2.2.2 Put away

Pallets with processed items at the inbound area are collected by forklifts and transported to a ground location near the buffer area. Here, they await transport up to the mezzanine or put away in the narrow aisle buffer area. Both alternatives require a change of trucks. The labels on the items are read in order to get direction to storage location, and after transportation, the operator puts the item on its dedicated position. No storage location confirmation is required. If the allocated slot is not available, the production support must be informed about it so they can handle the problem.

Some items are transported straight from the inbound area to the pick locations on the mezzanine floor, while others are placed in buffer while waiting for production support or the team leader to place replenishment orders for them. Replenishment orders from buffer are accumulated in the system and released once a day. The operator collects the orders from a printed picking list and operates a narrow aisle forklift. Items are picked and placed on a pallet near the buffer area. The operator must then retrieve a reach truck in order to transport the pallet to the mezzanine floor. When the pallet reaches the mezzanine, the operator reports the delivery in the system. The replenishment order must be processed by production support so that the articles can get storage allocations and labels.

Figure 24 illustrates a typical time distribution between the different activities performed in the put away process. The chart is based on data extracted from a RFQ, set on a yearly basis.

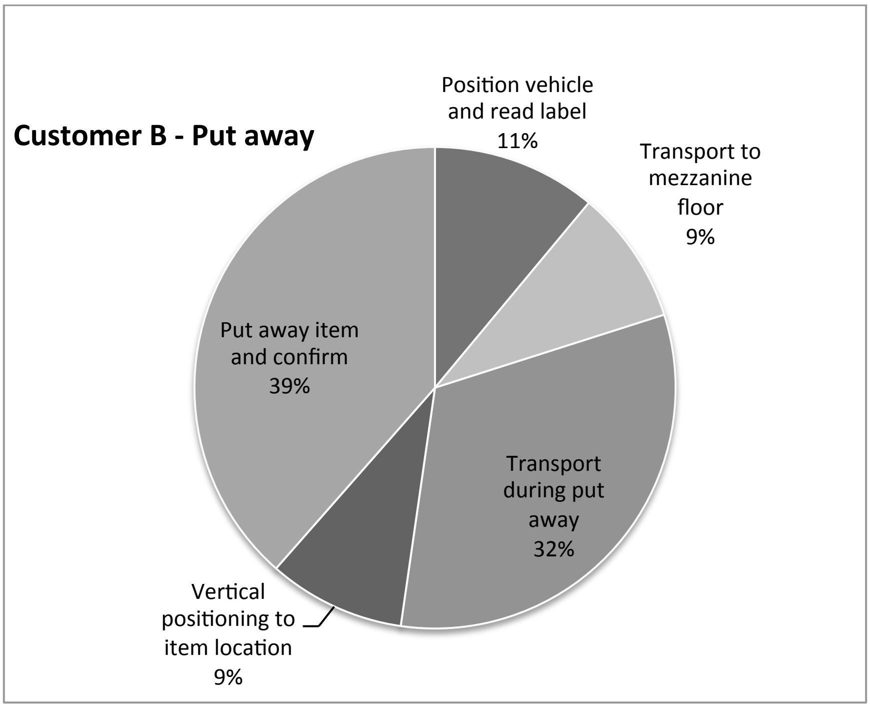


Figure 24. Time spent on put away activities for Customer B

The inbound process map that combines both reception and put away for Customer B is displayed in Figure 25.

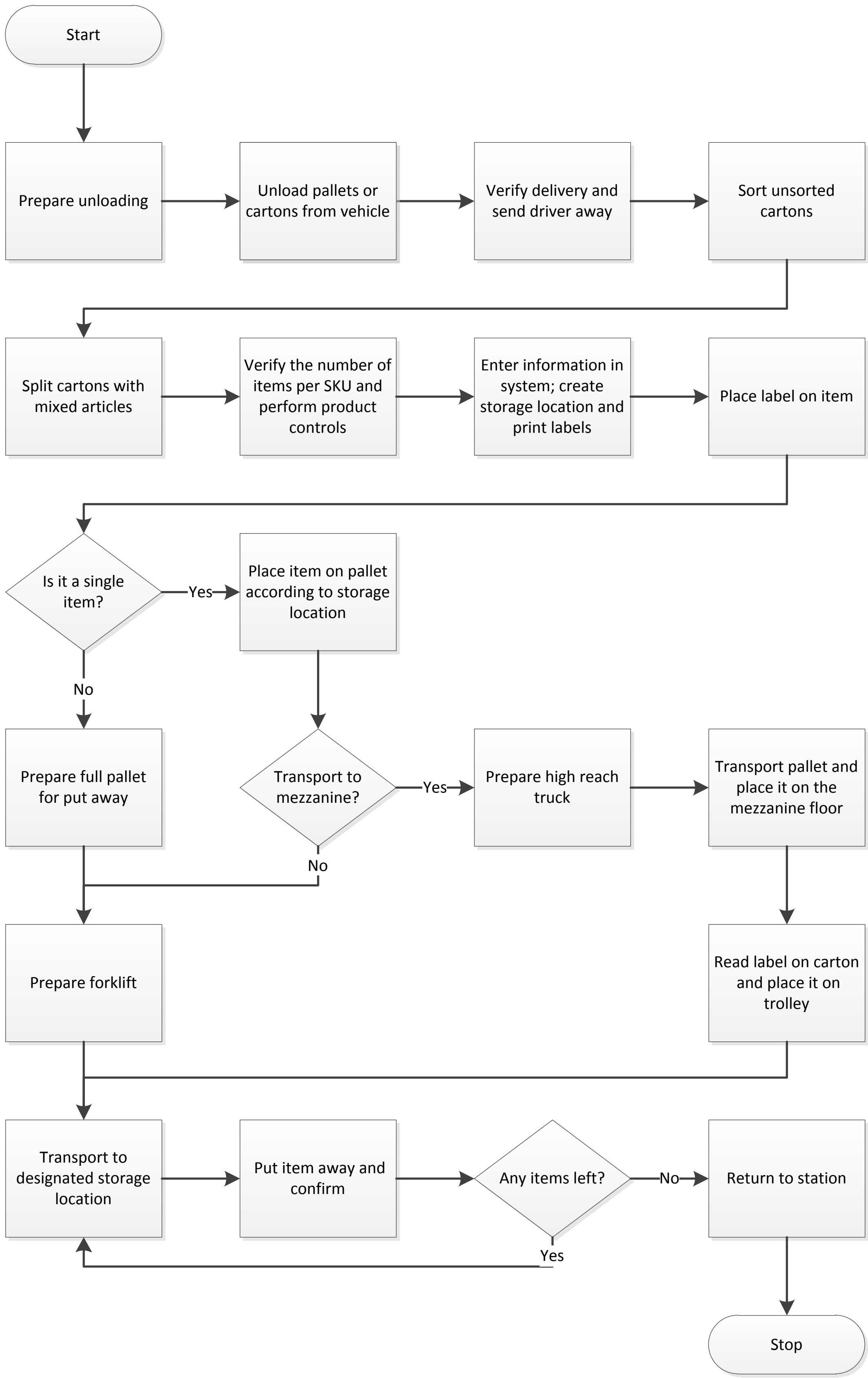


Figure 25. The inbound process for Customer B

4.2.2.3 Picking

There are usually about ten operators working with the outbound processes. SLL have five separate packing stations connected to an automatic roller conveyor. Each station has its own area, a computer with printer, a scale and shelves with packing material. The operator for each station is responsible for replenishing materials when needed.

The picking process starts when the operator selects a zone and initiates an order in the hand scanner. Labels for each customer order are processed when the operator scans the barcode on the printer, located in the middle of the mezzanine area. The scanner contains order information such as number of blue totes, which zone to pick from, number of order lines, locations etc. When there is a risk that the picked amount will exceed the volume of a single tote, the system gives an indication in the hand scanner and the operator can bring an additional tote.

A trolley with a four steps ladder is prepared with the required amount of blue totes. These can be of two different sizes (small or large) and the printed labels are attached on the totes. Each route consists of approximately nine totes and the system optimizes the number of orders on each route according to the amount of articles. For instance, if an order consists of more than 200 articles it usually requires the whole trolley.

The system calculates an optimal picking route to minimize transport distance. When the operator arrives at the pick location the operator scans the label on the carton, picks the correct amount of articles and put them in the right tote and scans the label the tote to get a new pick location.

Sometimes articles are placed on high levels and the operators must climb the ladder to reach them. Another time-consuming factor can be to open up and remove covers from boxes. If the articles are placed on a hanger, both the article number and the identity number must be checked manually since products with the same article number but different identity number can be placed next to each other. If a location is empty but the article exists according to the system, the operator must contact production support in order to correct the error. Replenishment cannot be ordered by hand scanner and must also be processed by production support.

The operator is also responsible for collecting and bringing back empty boxes to the recycling station. This can be time-consuming activity since the boxes often take up a lot of space on the trolley, which can result in additional transports back and forth.

When the orders are picked the operator places the blue totes on the conveyer belt that transports them to the packing station at the end of the mezzanine area. If the order is marked with KWD, the operator must transport these totes separately to the station to make sure that they are packed together since one tote is lacking a label.

Figure 26 illustrates a typical time distribution between the different activities performed in the picking process. The chart is based on data extracted from a RFQ, set on a yearly basis.

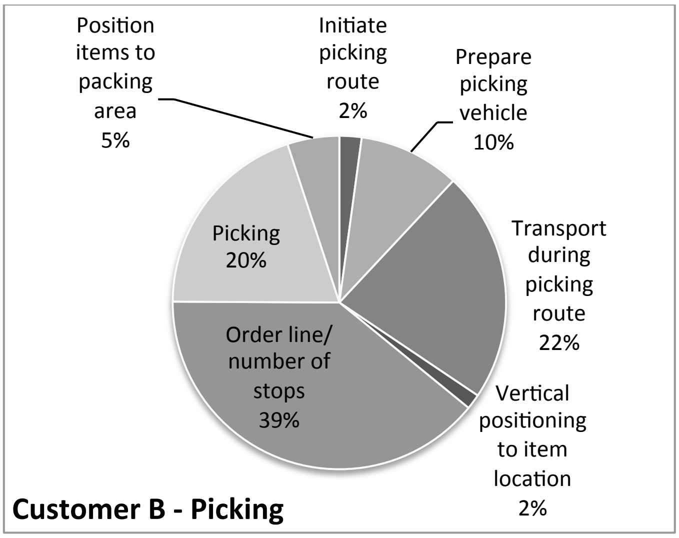


Figure 26. Time spent on picking activities for Customer B

4.2.2.4 Packing

The packing process is performed at the packing station, aided by the WMS. The operator takes a tote from the conveyor and scans the barcode to collect order information in the system. After this, a carton or plastic bag of appropriate size is prepared and the order is confirmed in the system to create labels and delivery notes. The operator checks the amount and article numbers before placing the items in the package. Except from deliveries outsides of the European Union, all packages are provided with a return note that is placed inside the package. The packages are then placed on the conveyer belt, which transports them from the mezzanine area to the ground floor where one operator is responsible for sorting them according to destination. The marks on the floor next to the belt display the destination of the pallets or cages, which facilitates the sorting.

Figure 27 illustrates a typical time distribution between the different activities performed in the packing process. The chart is based on data extracted from a RFQ, set on a yearly basis.

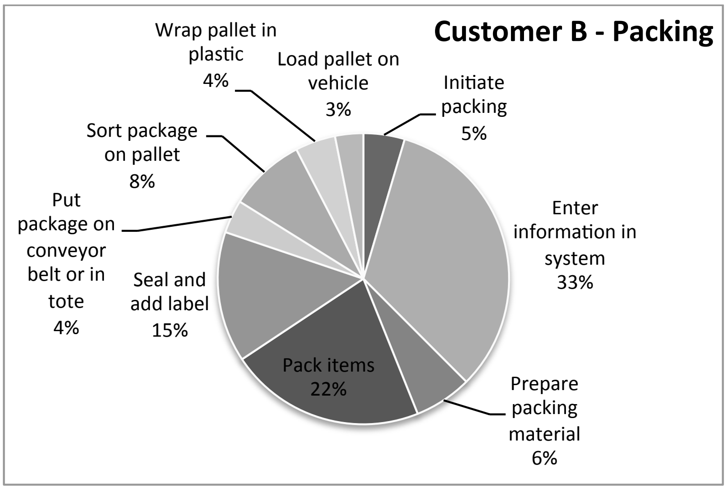


Figure 27. Time spent on packing activities for Customer B

The outbound process that combines both picking and packing for Customer B can be viewed in Figure 28 below.

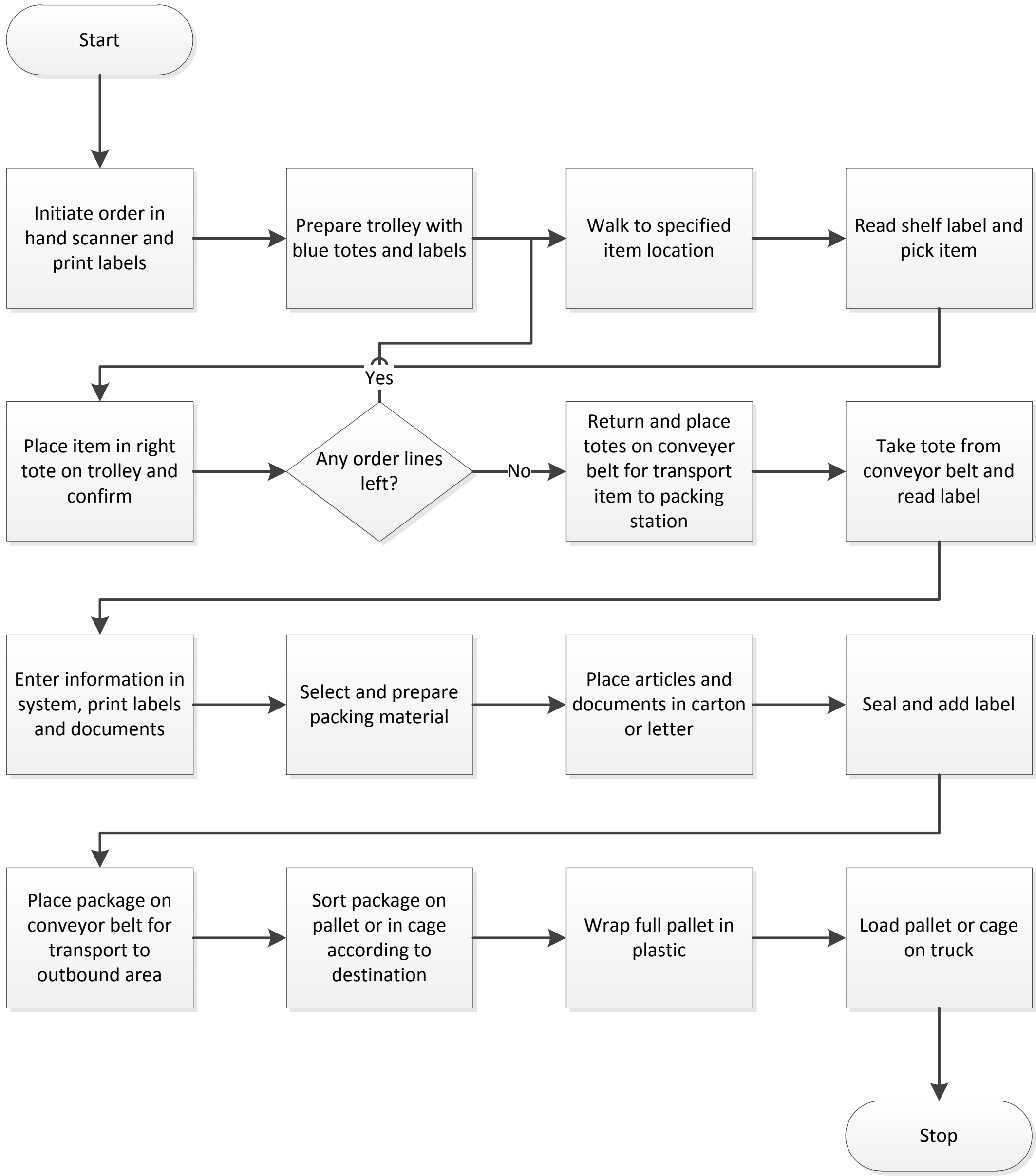


Figure 28. The outbound process for Customer B

4.2.3 Customer C

Customer C is a Swedish retailer of high-end wallpaper and is one of the smaller customers in the warehouse at Landvetter. SLL handles approximately 150-200 orders lines each day to different customers in Sweden, mainly by parcel deliveries. The processes are characterized of multi-pick of small and rather standardized items at six different levels in shelves at two standard wide aisles. Picking and put away articles in stock is performed manually with a trolley attached to an order picker forklift. Less frequently picked articles and special materials are collected and placed at higher levels on pallets, which have to be retrieved by a reach truck.

The operators also handles all administrative activities that are usually performed in the CT for other customers, e.g. booking of transport, handling of claims, customer contact etc. Time spent on these activities are estimated in hours by the end of the day and noted as VAS.

4.2.3.1 Reception

The inbound flow varies but consists of approximately one pallet of goods each day. The operators receive a delivery list of incoming goods and corresponding purchase order numbers for the week by mail.

When a delivery arrives, the pallets are placed near the packing station for processing. The operator signs a delivery bill in order to confirm that the goods have entered the warehouse. The incoming goods usually arrive in standardized boxes containing six or twelve items of same article number. The first step is to collect a carton from the incoming pallet and enter the purchase order number in the system. Article numbers are then compared and information regarding size of package, amount of items per package, amount of packages and batch number are entered before confirmation. The system processes the data and determines the optimal location for each item. Labels are printed and placed on the item, which is then placed on the trolley for put away in stock.

The operator must repeat the process for each SKU on the order, which means that a lot of time is spent walking between computer and pallet. In some cases the original labels are placed on areas of the boxes that are difficult to read, which complicates the process. Additionally, since the program bases the calculation for placement on the assumption that each box is of a standardized size, problem often occur when smaller boxes arrive. This results in storage space that is not fully utilized.

Occasionally SLL receive articles that have been on backorder, which needs to be handled separately in the system. The operator must also contact the customer in other cases, for instance if there is a discrepancy in the amount or between article number for delivered goods and the delivery list. Hence, a large portion of time is spent on customer contact or updating information in the system for the inbound process.

Figure 29 illustrates a typical time distribution between the different activities performed in the reception process. The chart is based on data extracted from a RFQ, set on a yearly basis.

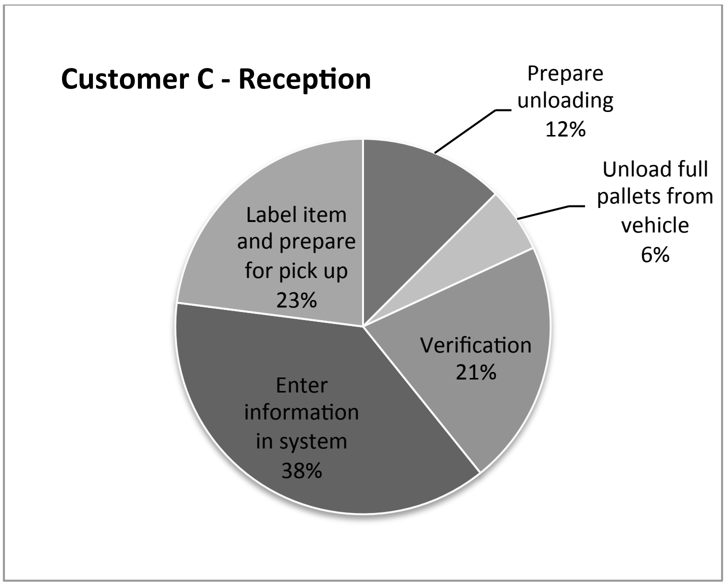


Figure 29. Time spent on reception activities for Customer C

4.2.3.2 Put away

The put away process for Customer C is characterized by many separate and relatively small cartons at different locations. The items on the trolley are placed so that the operator can read the labels. There is no pre-determined route for transporting the items to their storage location, but the operator strives to place them in an optimal way to reduce transport distance.

Nearly all items are placed directly at their pick locations, i.e. no buffer locations are used. During the put away process, the operator looks at the location on the label for the first box, transports the goods to the shelf, and leaves the item. The put away takes place at six different levels and the operator has to leave the forklift in order to reach locations on the floor. If an allocated location is occupied, the operator puts the item on the next available spot. A large portion of time is spent on finding available space and moving items around. Since the route is not pre-determined, the driver often transports the forklift back and forth several times in the aisles. When all articles are placed in the shelves, the process starts over again if there are more items to put away on the trolley. Since put away is performed without any help of computers or scanners, it can be very difficult to locate an article that has been misplaced.

Figure 30 illustrates a typical time distribution between the different activities performed in the put away process. The chart is based on data extracted from a RFQ, set on a yearly basis.

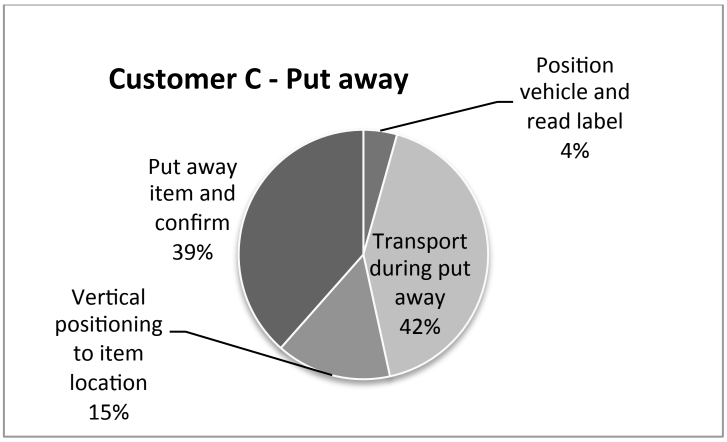


Figure 30. Time spent on put away activities for Customer C

The inbound process map that combines both reception and put away for Customer C is displayed in Figure 31.

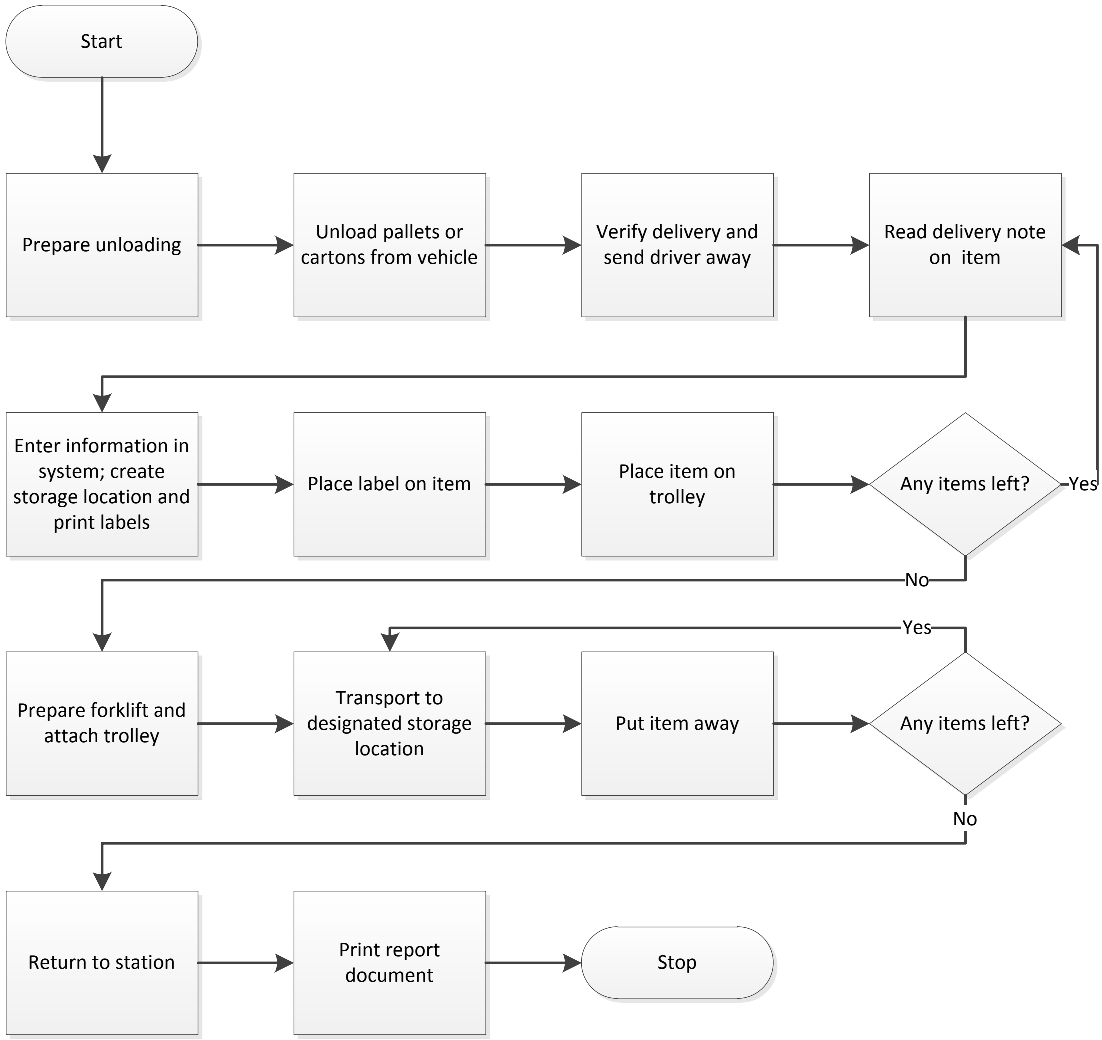


Figure 31. The inbound process of Customer C

4.2.3.3 Picking

The picking process starts when the operator prints a picking list from the system or takes one from the pile next to the computer at the packing station. Orders arrive continuously to the system during the day. The picking list contains information about article and batch numbers, and required amount for each customer. The orders or order lines are sorted to facilitate an U-shape picking route. Since each customer order often consists of a small number of order lines, several orders are picked at the same route. The operator uses a prepared trolley with nine fixed cartons, labeled A to I. These can represent maximum nine different customers. The trolley is attached to an order picker and the picking route begins.

The articles are picked in shelves where each level has a depth consisting of two positions named A and B. More frequently picked items are placed at position A, while others are place at the inner position B. Items located at position B on high levels can be difficult to reach and are often more time-consuming to collect. Articles of the same number are always placed at the same position, but this location can also consist of different batches (i.e. articles with the same article number but of different colors or variants.). It is therefore important to pay attention to both article and batch number when picking the order.

During picking, the operator looks at the first order line on the list and drives to the location. The article and batch number on the shelf label are compared with the numbers on the list and the operator picks the required amount of articles and places them in corresponding carton. The processed order line is then marked on the list and the procedure is repeated until there are no orders left. Empty cartons are collected along the way and returned to the packing station for recycling.

Figure 32 illustrates a typical time distribution between the different activities performed in the picking process. The chart is based on data extracted from a RFQ, set on a yearly basis.

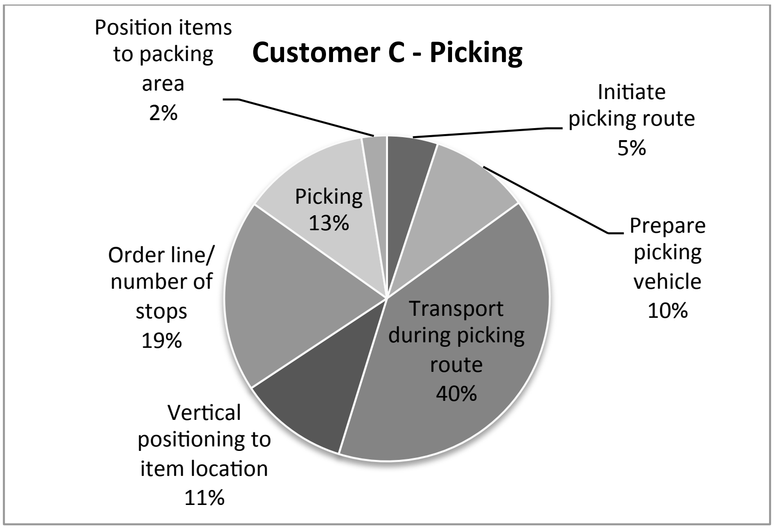


Figure 32. Time spent on picking activities for Customer C

4.2.3.4 Packing

The packing process begins when the trolley with processed orders is placed at the packing station. Usually there is one operator responsible for the final control and packing of orders. During high season there can be two operators performing these tasks.

The process starts with a brief overlook of the amount, type and size of items on the trolley in order to see if additional or special packing material is needed. The operator signs the picking list and places it in a dedicated spot next to the computer. The order is initiated in the system when the operator enters the order number to get corresponding information. If additional cartons are needed, the operator creates additional load carriers in the system and adds information about size and weight of these before printing labels and delivery documents. The process is repeated for all orders from the picking route at once.

After printing labels and documents, the operator sorts these on the packing station. One customer order is handle at a time and the procedure starts when the operator collects the items from the trolley and places them on the packing table. Packing material is prepared and folded into packages of appropriate size. The article numbers on the items are compared with the information on the delivery note to make sure it is coherent. If a mismatch exists, the operator corrects it or asks the operator responsible for picking the order to do it. Otherwise, the items are packed in the carton together with the delivery note and instruction of use and additional paper if required. The operator checks so that the delivery address is correct, seals the package with tape and adds the label on top. The packages are placed on pallets near the packing station.

The pallets are sometimes wrapped in plastic before the pick up in the afternoon. SLL is responsible for loading, but in some cases the truck driver performs this activity.

Figure 33 illustrates a typical time distribution between the different activities performed in the packing process. The chart is based on data extracted from a RFQ, set on a yearly basis.

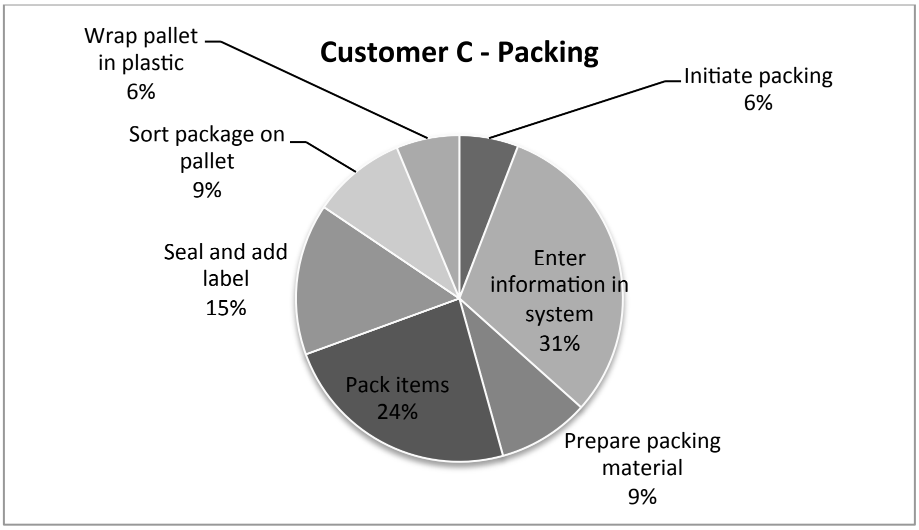


Figure 33. Time spent on packing activities for Customer C

The outbound process that combines both picking and packing for Customer C can be viewed in Figure 34 below.

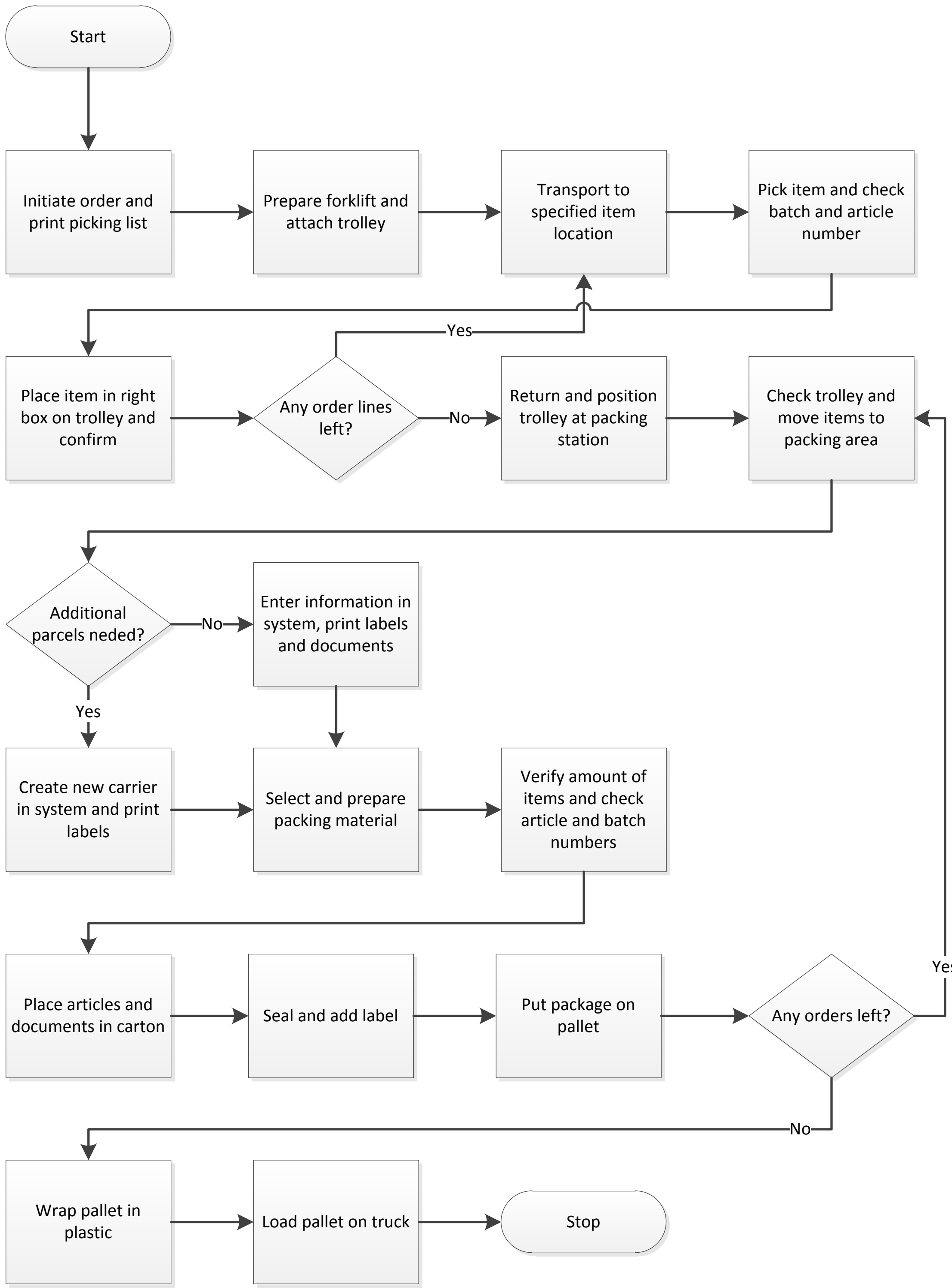


Figure 34. The outbound process for Customer C

4.2.4 Customer D

Customer D is a global printing group with production units in nine different countries. SLL handles inbound deliveries from some of these factories and outbound deliveries to customers of Customer D all around the world. The product range in the DC consists of mostly brochures and manuals for e.g. companies in the automotive industry. The articles are placed in seven very high and narrow aisles, with storage capacity up to 20 levels. Items are picked by operators in narrow aisle forklifts, where only one forklift can operate in an aisle at a time. Articles are often picked separately, but some orders require full boxes or pallets of one item. Fast moving and frequently picked articles are placed in a small shelf called ELC near the outbound area. A shelf location on the ELC contains items of the same article number but different identity numbers, which must be considered during picking. Articles in this shelf often leave within a week.

The outbound process for this customer is characterized by relatively low frequent picks and scrapping when new product models arrive. SLL mainly uses dynamically allocation of slots when determining storage locations for articles. In general, there are two or three operators handle the operations for Customer D.

4.2.4.1 Reception

The size of inbound deliveries varies on a weekly and daily basis. There is a peak in demand twice a year, in March and May. The operators unload the pallets to the receiving area and receive a delivery bill containing delivery information. Pallets often consist of mixed orders, which must be sorted before information can be entered in the system and labels can be created.

When a pallet is placed at the inbound area, the operator removes the delivery note of a package and enters the purchase order number in the system to receive information regarding the order, e.g. article number, amount or packages and items. The operator selects the appropriate size for the article (e.g. letter, small, medium or large box) in order to allocate a storage location to it. If articles are delivered in batches, the operator selects ELP in the system. ELC is preferred if the order consists of separate and small items. When all information is entered in the system, the delivery is confirmed and labels are printed.

Figure 35 illustrates a typical time distribution between the different activities performed in the reception process. The chart is based on data extracted from a RFQ, set on a yearly basis.

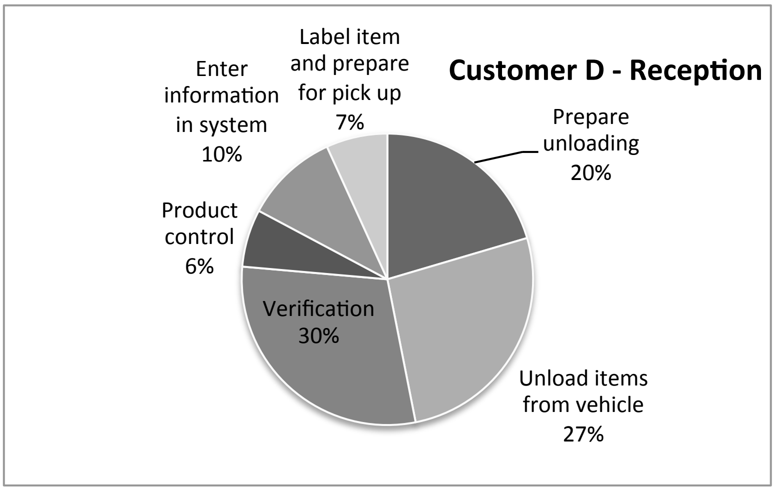


Figure 35. The time spent on reception activities for Customer D

4.2.4.2 Put away

The items are labeled and either placed straight on the ELC shelves or on a pallet where they await transportation to the narrow aisles by a forklift. The operator puts articles with locations in the same aisle on the same pallet. Since no computers or scanners are used, the route is planned manually. The operator looks at the shelf location on the label, transports the item there and leaves it. All articles are distributed continuously in the narrow aisle and the procedure is repeated for all cartons on the pallet are processed.

The operator returns to the station and prints a report document for all incoming orders to confirm the put away. All incoming goods should be processed within 24 hours and the operators can choose to allocate the workload within this period in order to keep the productivity at a steady rate.

Figure 36 illustrates a typical time distribution between the different activities performed in the put away process. The chart is based on data extracted from a RFQ, set on a yearly basis.

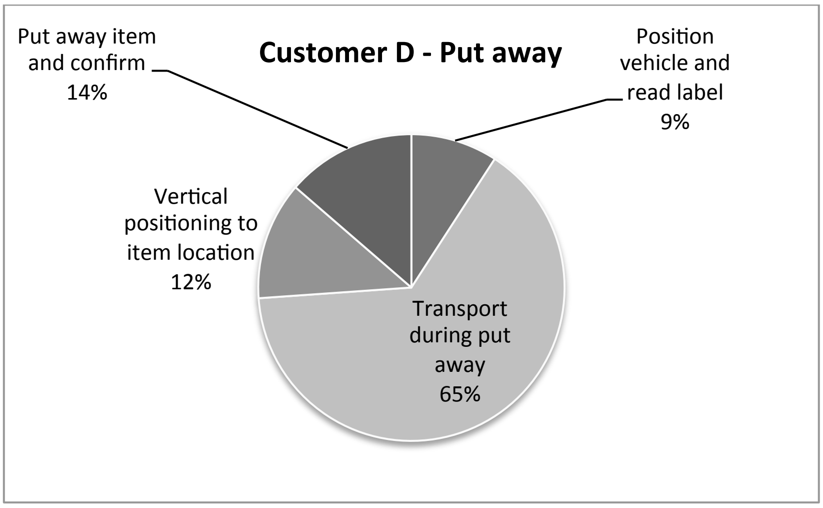


Figure 36. Time spent on put away activities for Customer D

The inbound process map that combines both reception and put away for Customer D can be viewed in Figure 37.

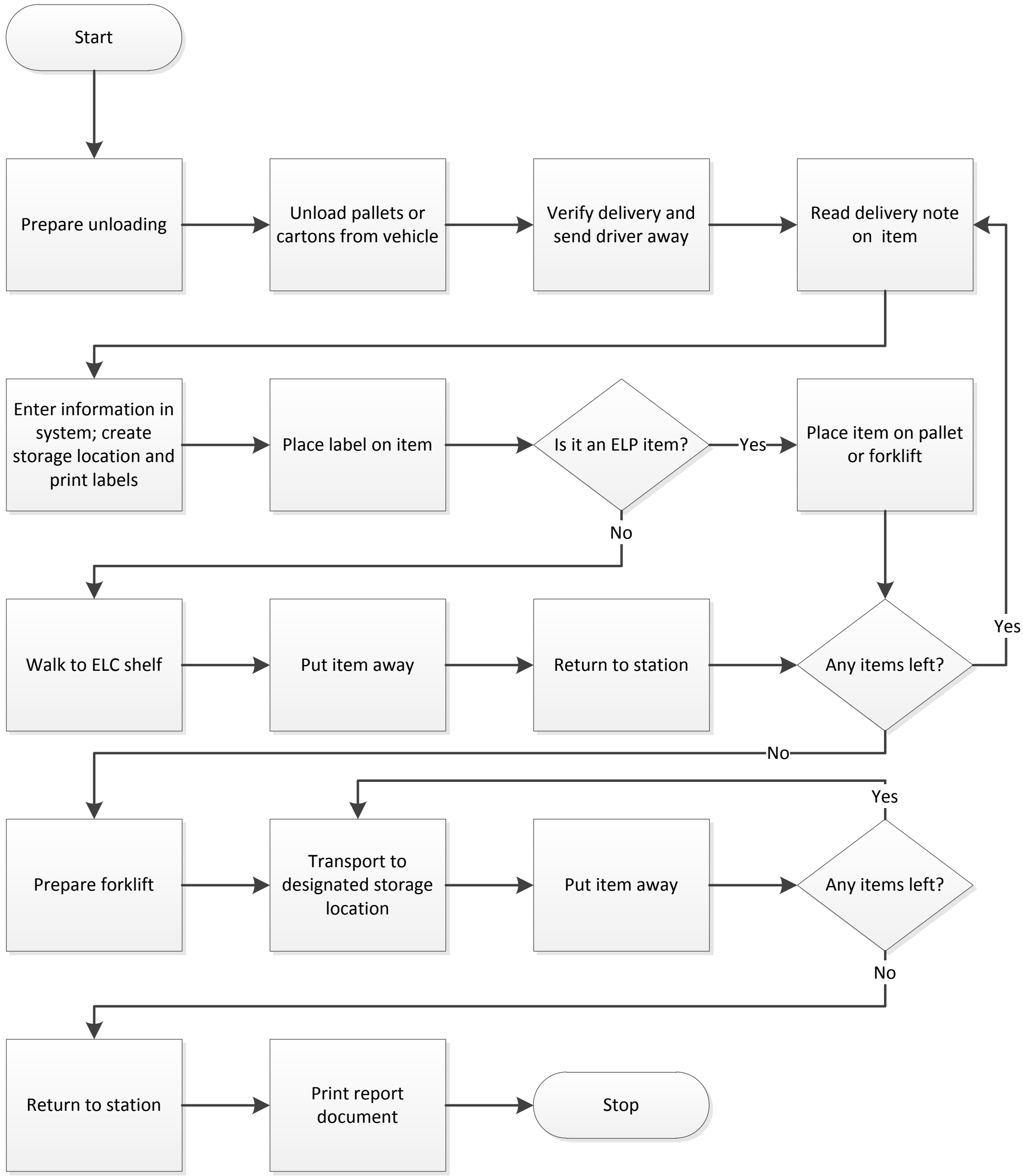


Figure 37. The inbound process for Customer D

4.2.4.3 Picking

Orders are released in the system the day before and picking lists are printed each morning and continuously during the day. SLL handles different types of outbound deliveries and the most significant one is the daily delivery back to the manufacturing facilities in Mölnlycke.

The picking process is characterized by multi-picks of separate items from their original boxes, which often require additional handling and repacking of boxes. Packages to Mölnlycke also can not contain items of different article number, while articles can be merged in other cases. These deliveries also require additional hours for VAS, e.g. scrapping of obsolete items, customer contact by mail or phone etc.

The picking process looks almost the same for all orders. Orders to Mölnlycke are picked one at a time, while other parcel orders can be combined in one picking route. This is determined by the operator, who checks the printed picking lists and chooses which ones to process on the route. An order that consists of many lines is often picked separately. The picking is performed without hand scanners and the computer has calculated the optimal picking route for the order, which is displayed on a printed picking list. The operators can also merge different picking lists and pick several orders at the same time.

The picking route begins when the operator prepares the forklift, checks the location on the list and drives there. The forklift operates in small aisles and it must connect to a magnetic trail in the floor so it is stabilized during the process. The forklift is designed to move both vertically and horizontally at the same time, except at its highest position. The operator checks the shelf label and picks the items by hand. The article number and amount is checked against the list before the article is placed on the pallet on the forklift. Different aisles have different number of levels and shelf heights, designed for small, medium or large boxes. Picking can be performed at maximum 20 levels and the operator must leave the forklift when picking from floor location.

Some picks from pallets require that the operator change forklift to collect the items. A combi truck is used to collect and transport the pallet to the end of the narrow aisle. The pallets are temporarily placed there while the operator collects a low lifting truck and transport the pallet to the outbound area. Here, the items can be collected from the pallet and the operator must use the same procedure in order to transport the pallet back to its location.

Figure 38 illustrates a typical time distribution between the different activities performed in the picking process. The chart is based on data extracted from a RFQ, set on a yearly basis.

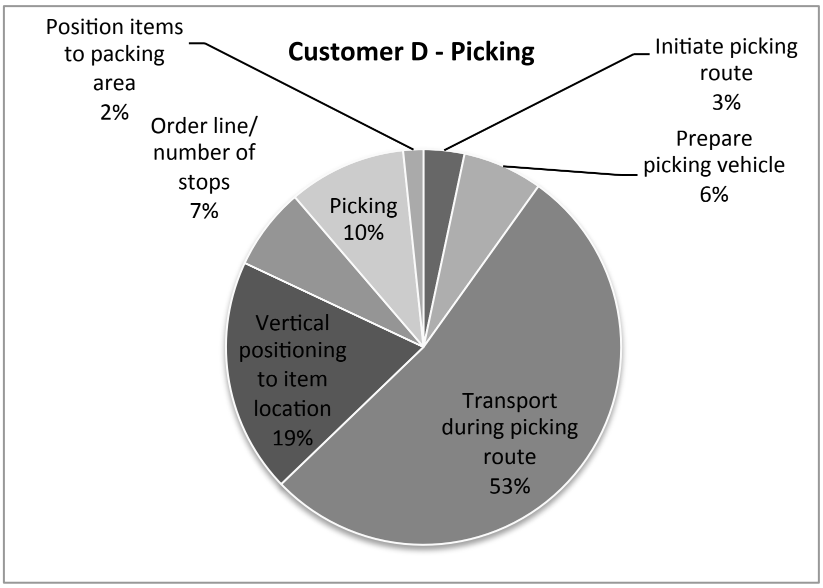


Figure 38. Time spent on picking activities for Customer D

4.2.4.4 Packing

When all orders are processed, the operator returns with the articles to the packing station and prepare for packing. Customer orders are processed one at a time and the operator looks at the list and enters the order number in the system in order to get information regarding the specific order. Packing material is prepared and all article numbers are compared with the picking list before the items are placed in the cartons. The packages are then sealed and the operator needs to add information regarding size, weight and number of packages in the system before confirming the order. Additional load carriers are created if they are required. Delivery labels and delivery notes are printed and placed on the boxes, which are sorted either on pallets or in cages.

Some deliveries are sent by letter if they weigh less than two kilos. These orders are often picked during one route, depending on the amount of items. The letters are weighed and information is changed in the system if needed. The documents are placed in the letters, which are sealed and sorted in blue boxes according to their end destination, either internationally or domestic deliveries. The picking lists are filed to confirm that the order is completed.

Truck performing milk run deliveries are arriving twice a day to collect the goods. A cage with deliveries by Posten needs to be transported to the end of the DC before pick up. Other forwarders collects the goods at the outbound area near the packing station at predetermined times.

Figure 39 illustrates a typical time distribution between the different activities performed in the packing process. The chart is based on data extracted from a RFQ, set on a yearly basis.

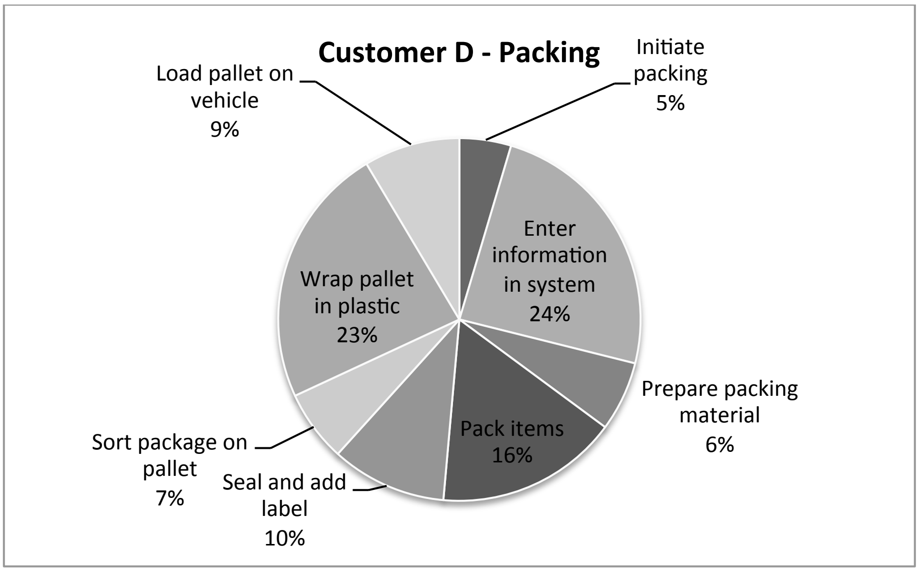


Figure 39. Time spent on packing activities for Customer D

The process map for Customer D’s outbound process (that considers both picking and packing) can be viewed in Figure 40.

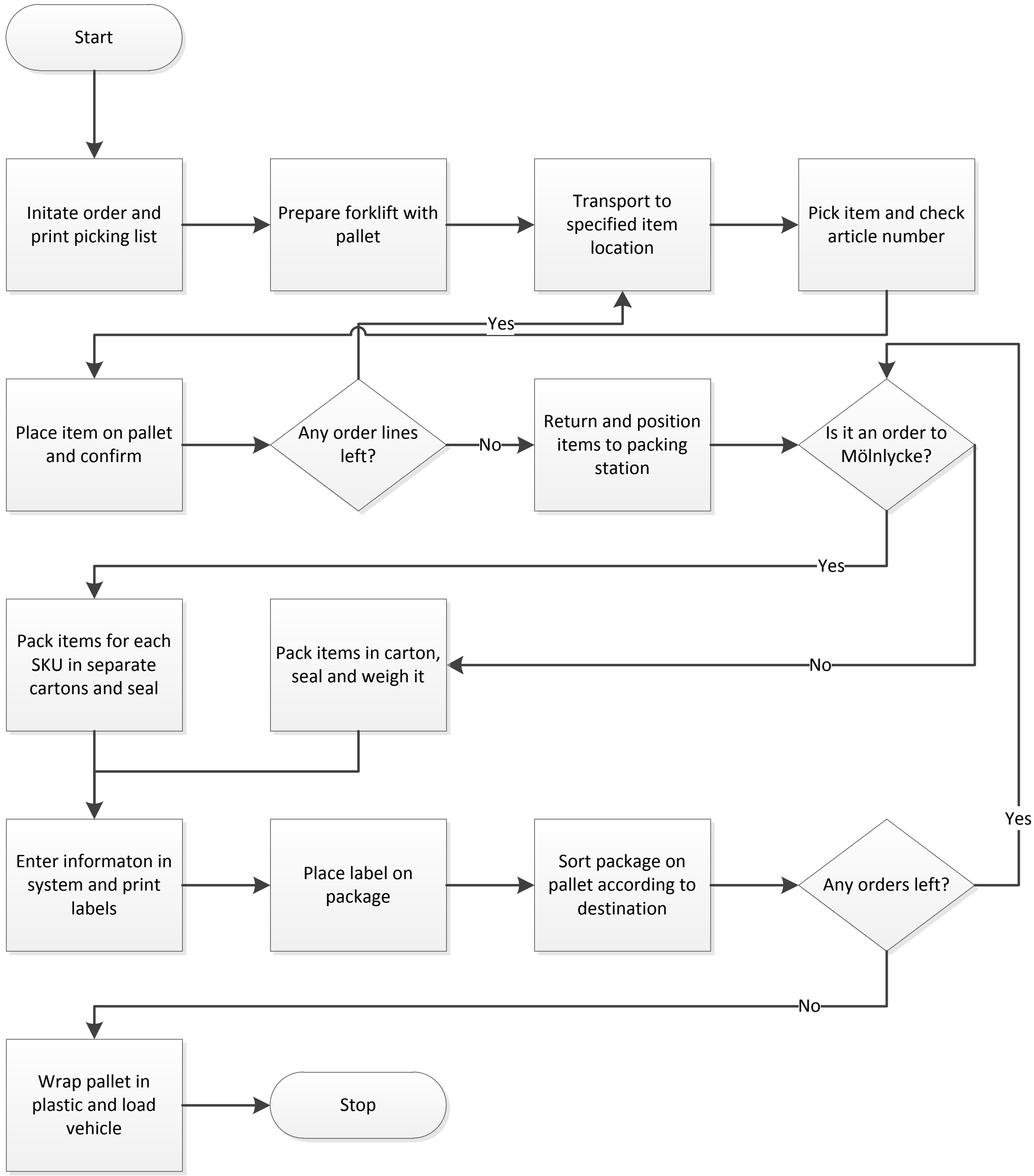


Figure 40. The outbound process for Customer D

4.2.5 Customer E

Customer E is a Swedish retailer of a broad range of products for farming, gardening and agriculture. Their DC is handled by SL and located in Torsvik outside of Jönköping. Direct deliveries are made from the DC to different retailers in Sweden but customers can also place orders online, which means that SL also handles smaller deliveries to end consumers as well.

SLOG has 30 full time employees and between 10-25 are temporary workers depending on seasonality in demand. The warehouse is divided into different zones according to the characteristics of the products:

1. Dog and cat
2. Full pallets
3. Deep pallet racking
4. Combination of articles
5. BBP - store packages
6. Online orders
7. Rakes and long handheld items
8. Smaller items at the mezzanine floor
9. Sensitive or dangerous goods
10. Heavy goods

The main part of the ground floor consists of wide aisles with pallet racking. Two aisles contain deep racks with buffer locations and there is an open floor at the end of the warehouse for larger goods that cannot be placed in racks.

The storage area on mezzanine floor contains articles for both online orders and regular orders for retailers. There are several rows of shelves containing smaller items at five different levels, while large and bulky items are usually placed on the floor. Packing of all online orders takes place on the mezzanine and if articles are placed on the ground floor, they must be transported to the mezzanine floor for packing.

4.2.5.1 Reception

One or two team leaders are responsible for the administrative planning of inbound deliveries, e.g. allocating slots, receiving drivers, division of workload etc. The truck driver is responsible for unloading the pallets from the vehicle to the inbound area for deliveries within Sweden, while SLOG unloads containers or foreign deliveries. Some parcel orders can arrive unannounced, as long as there are less than six packages.

When a container with separately loaded cartons arrives, the unloading process is noted as VAS activities. SLOG gets information from Customer E about how many items each pallet should contain. The cartons are placed on pallets, which are later covered in plastic and transported to a sorting area where they await further processing before put away.

One operator is responsible for verifying the incoming goods and entering information in the system. After entering the specific purchase order number in the system the operator can see how many pallets and article numbers the delivery consist of. The operator chooses appropriate storage locations and creates new labels. All pallets are checked before they are labeled and one article number is processed at a time. If any damages or deviations occur, these are reported to Customer E. The receiving process ends when the delivery note is signed and placed in a box where all documents are collected by the end of the day.

4.2.5.2 Put away

Full pallets are collected by forklifts and are transported to their locations. Each forklift driver has an objective of handling 20 pallets per hour and two pallets can be transported on the same route to save time. The operator scans the item label with a hand scanner and receives the location. All pallets are placed in wide aisles and buffer levels at low heights. After leaving the pallet the operator enters the check figure in the scanner and returns to the inbound area to collect another pallet.

4.2.5.3 Picking

Picking on the mezzanine floor for online orders are performed by list, while retailer orders are processed by hand scanner. Smaller items picked for retailer orders are placed in shelves at low level, while more irregular products are placed on the floor. The routes are performed by trolley, but sometimes the operator must use a forklift to collect bulky items. Other characteristics of this procedure is that some items require measuring and cutting (e.g. hoses and tubes), which sometimes requires two operators.

Picking at the ground floor is similar to other picking processes performed by forklift (usually order pickers) and hand scanners. Some items are heavy or bulky, which means that some routes are more time-consuming than others. For instance, if items are very long the carton must be secured by tape to the forklift so that it does not rollover. When an order is processed the operator covers the pallet in plastic and transport it to an allocated slot at the outbound area.

4.2.5.4 Packing

Packing of online orders is performed at one end of the mezzanine floor. There is a roller conveyer that transports the orders to the packing station where two tables, three computers and two plastic strap machines and are available. The operator scans the picking list and enters information into the system, e.g. size of carton, number of cartons etc. and prints delivery notes and labels. The packing procedure can look very different between different orders due to the size and shape of the articles. Thus, each order is unique and requires its own specific packing. The operators use cartons, hard plastics and plastic bubbles for wrapping. Some items require full pallets, while others are packed as parcels. There are specific rules and measurements that decide whether the delivery should go by currier or by truck. All packages are later transported on pallets from the mezzanine to outbound area on the ground floor.

All pallets at the outbound area are processed by the end of the day. An operator compiles the deliveries and make sure that no goods are damaged or misplaced. After the confirmation, the truck drivers are responsible for collecting pallets and loading the trucks.

5 Development of calculation tool

This section will discuss in detailed the four different standard processes and their corresponding activities, which represent the framework of the calculation tool. Each section will display a process map that illustrates the main elements of the standard process. The analysis will describe how the foundation of the segments was created, the results of the data collection and other relevant factors that impact the specific activities. Furthermore, the layout of the calculation tool will be presented, and the tool will be tested in order to compare the generated values with real situations and add-ons for time allowances are established. Finally, the quality of the study and the calculation tool is assessed.

5.1 Reception

This subsection will describe and discuss in detail all standard activities for the receiving process, from preparation of unloading to labeling of items for put away. All elements included in this process are displayed in Figure 41.

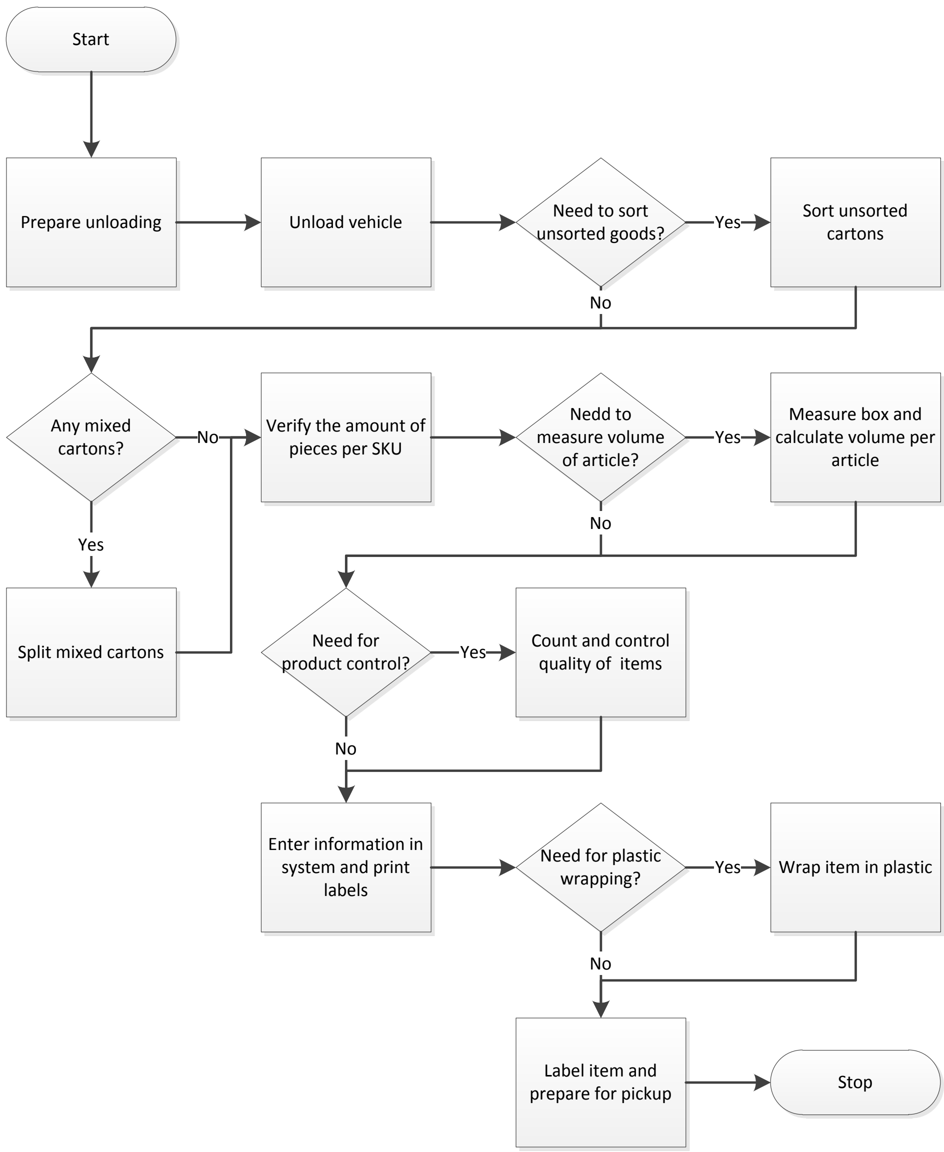


Figure 41. The reception process

The reception process is one of the most complicated sections when it comes to determining the needed manual labor and developing standard times for required activities. It is also the section with largest varieties and uncertainties in the collected data sets, especially for the unloading section.

5.1.1 Prepare unloading

Prepare unloading considers activities such as print the unloading list, prepare pallets and forklifts, plan unloading, open gate, remove seal from container, receive driver etc., i.e. all activities required in order to start the unloading process. This activity also includes additional time for signing the delivery and sending the driver away, even if this might be performed as an isolated event after the goods are unloaded.

Two alternatives are available for this section, one for deliveries by containers or trucks and one for couriers. The second alternative is rather simple in comparison with the first one, which resulted in a clear distinction between the two. Receiving a courier delivery does not require much preparation at all. In general, the operator receives the driver, opens up the gate and signs the bill. Only one observation was made for this alternative and the team leader at Customer B validated the data.

Preparing the reception of containers and trucks is more complicated and several observations were made, resulting in a large spread of times. In reality, the time is dependent on the specific situation, the type of delivery, vehicle etc. In general, preparing unloading of containers is more time-consuming than for trucks. However, the choice to merge the two into one alterative in the final calculation tool was made due to the high level of uncertainties within each alternative and in order to smooth out the variations in data set.

Furthermore, since this process also includes elements such as checking the delivery list in order to plan how the sorting should be performed, this activity also depends on other factors such as number of cartons, number of SKUs, available area at unloading station, unloading equipment etc. This made it even more complicated to set a reliable average time for this alternative.

Finally, the number of required operators for this activity is also an ambiguous factor. For instance, preparing an unloading with a Long John might require nine more or less active operators, while preparation of a truck or courier deliveries might only concern one operator. However, an assumption is that the data represent the actual time it takes for one person to perform this activity, even if it is gathered from situations where several operators were present but less active.

5.1.2 Unload vehicle

The unloading starts when the first carton or pallet is moved from the vehicle and ends when the last one is placed on the designated unloading area. This section is independent of the type of vehicle used (even though separate cartons generally arrives in containers or by couriers and pallets in trucks), its volume or the utilization rate. Only the type and amount of items (i.e. pallets or cartons) and the type of loading (i.e. sorted or unsorted) are considered as significant time drivers in this section. In the case of loose cartons, also the number of SKUs affects the time for unloading.

After observations of different types of unloading procedures, the following combinations were set as alternatives in the calculation tool:

Unload loose cartons

A delivery with loose cartons can either be sorted or unsorted. Unloading this type of delivery can be performed by Long John or by placing cartons on pallets. When unloading cartons by Long John, the model builds solely on observations made at Customer A, where seven to nine operators were constantly active with either placing cartons on Long John, sorting cartons on pallets or transporting pallets to sorting area. Furthermore, since all data is collected from one customer, a transport distance of approximately 50 meters to the sorting area is considered in the data set.

When unloading cartons by placing them on pallets, observations were made at Customer B with two or three active operators and a transport distance to the sorting area of approximately 20 meters.

This section assumes that all cartons are completely sorted on pallets according to variant, PO-number, SKU or similar factors after the unloading process. During observations, it became clear that the time for this activity is mainly driven by the amount of SKUs and number of cartons. Thus, input data for this section relates to these factors. The complexity of the unloading activity increases with both elements and it is difficult to set a limit where the variations are too large to handle, i.e. when sorting must be performed at a later stage in the inbound process. The data for these sections regards situations where the maximum number of SKUs were 69 and the cartons were 946. Thus, it is difficult to predict what happens when deliveries exceeds these amounts.

Furthermore, in some circumstances there have been deliveries described by the operators as “somewhat sorted”. Data from these observations have been treated as if the deliveries were unsorted, a decision made after analyzing and comparing data from situations where deliveries were either completely sorted or completely unsorted.

Since the values in the calculation tool are set as man-hours (i.e. the values are obtained by multiplying the number of active operators with the elapsed time), the time it takes to unload a vehicle by placing cartons on pallets is less than using a Long John. This can be a bit contradictive, since using a Long John has been described as a very effective and efficient way to unload a container with an average total time that is far less than the other alternative. An example of the time differences between the alternatives can be viewed in Figure 42, where the same number of cartons and SKUs are used as input.

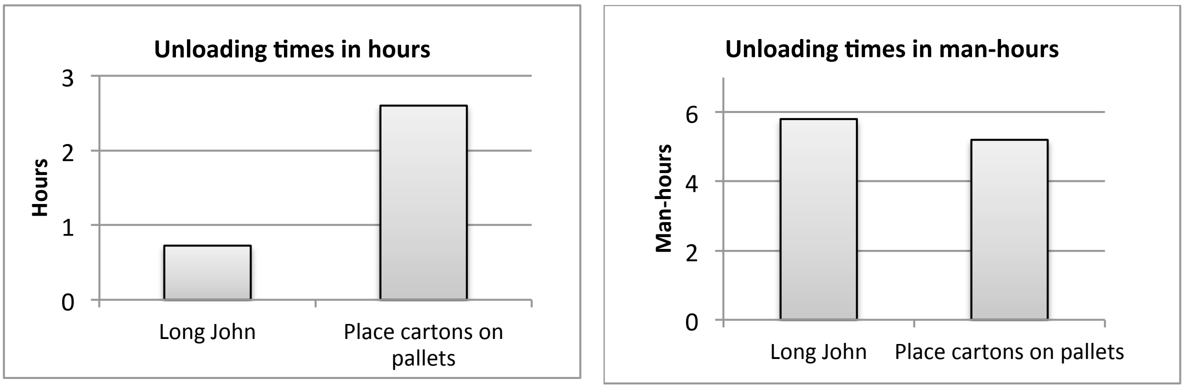


Figure 42. Comparison of times for unloading loose cartons

However, it can be difficult to make a fair comparison based on the observations at SLL since they consider two different customers, where the amount of operators varies a lot. For instance, there are almost always seven to nine active operators at Customer A when unloading by Long John, while in general there are two to four operators working with placing cartons on pallets for Customer B. A way to gain better understanding and compare the two alternatives would be to observe situations where the amount of operators were the same for both cases. Furthermore, the optimal number of operators performing the activity must also be considered to make a fair comparison. There are several reasons why it might be more adequate to use a larger number of operators when unloading with Long John. One example is that it is easier and more efficient to strategically place these around the conveyer belt, than letting them work randomly inside the container with placing cartons on pallets.

Unload full pallets

Containers or trucks containing full pallets can be unloaded by operators using pallet jacks or low lifters with platform, and the pallets are transported directly to the inbound or sorting area. The time for this activity depends on the choice of vehicle as well as the transport distance to the designated area. However, the calculation tool builds on observations and assumptions that the distance does not exceed 20 meters and an average time that covers the transportation back and forth has been calculated. Thus, the only input in this section concerns the amount of unloaded pallets and the type of vehicle used.

The pallets may be piled on the forklift in different ways, e.g. single, double or triple stacked. However, the type of stacking is not considered in the calculation tool since it does not have a significant impact on the total time for the activity. For instance, it was clear after several observations that the forklifts operated at similar speed no matter if the pallets were singled or double stacked.

Calculations behind the unloading section

The collected data for this section turned out to be very difficult to process since many different factors were linked together, which affected the output. Many observations were needed in order to see any connections between the collected values, and each observation could span over several hours. At first, the collected data was consolidated in a matrix that considered both number of SKUs and cartons. However, it turned out to be difficult to complete the matrix without doing estimations with high degree of uncertainty. Thus, other alternatives to set the standard times were evaluated.

This lead to a development of an equation in order to generate values for the unloading process with Long John. Since the number of SKU and the number of cartons are the main time drives for this activity it was necessary to create an equation that regarded both parameters. During the data analysis, values from four unsorted deliveries unloaded with Long John were identified and used as foundation for the calculations. The number of cartons for the four deliveries was almost identical and could be paired together: 450 and 451; 390 and 395 (see *Table 1*). It was assumed that the time differences between these deliveries were directly related to the number of SKUs since the number of cartons was the same. The additional time was divided with the additional number of SKU for each pair and a value of 70 seconds/SKU was obtained. Both pairs indicated similar results; 70 seconds and 70,5 seconds. Hence, it was assumed that for each additional SKU there was a time increase of 70 seconds.

	Number of cartons	Number of SKUs
Delivery 1	450	64
Delivery 2	451	45
Delivery 3	395	11
Delivery 4	390	53

Table 1. Samples of deliveries used for calculations

The next step was to calculate an unloading time per carton that was representative for an unloading that only contained one SKU. By doing this, a minimum unloading time per carton was obtained that was independent of the number of SKUs. The original times for the four deliveries were subtracted with the number of SKUs multiplied with the 70 seconds for each SKU. For all four alternatives a value of 37 seconds was obtained (37,4 to be exact), which is the average value for the four deliveries.

37,4 is the time in man-seconds it takes to unload one carton with a Long John. This value must be multiplied with the number of cartons and added to the number of SKUs that are multiplied with the value of 70.

$$Unloading\ time = 37{,}4 * number\ of\ cartons + 70 * number\ of\ SKUs$$

Equation 1. Time for unloading with Long John

Equation 1 was tested and validated with very good results on other observed times for this activity. It is assumed that this equation also applies for deliveries with sorted cartons. However, the equation was only tested on one sorted delivery and more observations might be needed to confirm this statement.

A similar procedure was done for unloading sorted and unsorted carton deliveries with placing cartons on pallets. It was assumed that the SKU-variable increased with the same factor as for the unloading with Long John, i.e. 70. This assumption was also strengthened by testing the collected data. Equation 2 displays the formula for unsorted goods and Equation 3 the formula for sorted goods.

$$Unloading\ time = 33 * number\ of\ cartons + 70 * number\ of\ SKUs$$

Equation 2. Time for unloading unsorted cartons by placing them on pallets

$$Unloading\ time = 24 * number\ of\ cartons + 70 * number\ of\ SKUs$$

Equation 3. Time for unloading sorted cartons by placing them on pallets

The equations for this section are only tested and validated with data ranging from 18 SKUs to 69 SKUs and with cartons ranging from 390 to 946. Thus, it is difficult to know what happens if the input data goes beyond these intervals.

5.1.3 Sort unsorted goods

Sorting of unsorted goods is mainly performed for goods delivered on pallets and concerns activities such as removing plastic from pallets and sorting cartons on new load carriers.

This section is assumed to depend solely on the number of cartons that require sorting. An average time has been calculated that considers the full processing of one carton, which is independent of the amount of cartons and SKUs that the delivery consists of. However, in reality the complexity of this activity increases with the number of SKUs, the size and weight of the carton, how difficult it is to localize the item or read the label etc. A better way to consider these different features would have been to develop a matrix and base the calculations on both the number of SKUs and cartons. However, this was considered to be too detailed to be covered by this study.

Furthermore, the collected data only concerns situations with less than 40 different variants or SKUs. Thus, it is difficult to predict what happens with the average time if the amount of SKUs exceeds this limit.

When cartons have been sorted during unloading (which is normally the case for deliveries with separate cartons), the first field in this section is left empty. However, mixed cartons containing several SKUs can exist for all deliveries, which require additional handling, e.g. to open up cartons, sort mixed articles into new cartons, count articles and mark the item. This activity is also dependent on the number of SKUs and items in each carton. However, since the amount of mixed cartons is relatively low for each delivery, these factors are not considered to have significant impact on the total time for the sorting activity. Therefore, the time to handle mixed cartons is fixed per carton, which is a reasonable choice.

5.1.4 Verification

Verification is performed when the sorting is completed and this activity involves counting the number of pieces per SKU to make sure that all ordered items are delivered.

This is an activity that can be performed by one person, but in most observed cases at SLL there are two operators doing this together. When analyzing the collected data two things became clear. Firstly, working together did in general not save time in comparison to working alone. In contrast, some observations showed that working together increased the total time for verification, mainly due to misunderstandings and lack of communication between the operators.

Secondly, the average time for processing one carton increased mainly with the amount of variants or SKUs. However, there was no clear connection between the data when using only the number of SKUs and cartons as time parameters. Therefore, several other factors were evaluated such as number of pallets, congestion at sorting area, size of cartons and the operator's ability to read and translate information into calculations. Some operators were very good at processing information and performing calculations, while other were using calculators. It was difficult to consider all these parameters in one time equation, thus an average value per carton was calculated and used in the calculation tool to consider as many different circumstances as possible.

5.1.5 Volume control and calculation

Volume control and calculation is performed on sorted and verified goods in order to collect and add information regarding the size of the items in the system, which facilitates the picking process later on. The time for this activity is assumed to be fixed per measurement or sample and involves measuring a carton, calculate its total volume and divide it with the amount of items inside.

This activity is only performed for some customers and is often associated with arrival of new products, e.g. each time a new SKU enters the warehouse. Furthermore, one calculation can be used for several different SKUs if the cartons are of the same size and contains the same amount of articles. Thus, the number of measures or samples needed is very dependent on the characteristics of the specific delivery. For instance, the operators at Customer A estimates that they perform between two and five measurements per delivery, while Customer C or D do not perform this activity at all.

In general, the time spent on volume control and calculation is considered to constitute a very small part of the total time for the reception process. Therefore, only a few observations were performed to get an understanding of the average time for this activity.

5.1.6 Product control

Product control includes the time it takes to control articles in one carton and it involves opening up boxes, checking quality of items, and measuring moisture level and other factors stated in the customer contract. One operator was performing this activity in most of the observations. However, several operators might be working with this together if the delivery is large. Product control can also occur simultaneously with other activities such as verification and volume control.

The time is assumed to be fixed per measurement or sample, but it depends on many different factors in reality such as the number of items per carton, visibility of tags with article numbers etc. Product controls for two different customers were observed, and the times showed a significant scatter. However, this section of the reception processes is also considered relatively small in relation to other activities and therefore the calculated average time per sample is assumed to be appropriate.

The number of product controls needed is often stated in the contract and it can therefore be difficult to quantify this input in the calculation tool. However, most operators at SLL checks one carton per pallet or SKU in general, which can be an appropriate guideline. If no product control is included in the contract, this section is left empty.

5.1.7 Enter information in system

Entering information in the system is performed in order to allocate storage locations for the incoming goods. This activity concerns the time it takes from when the operator starts working in the system, until the label is printed. The activity includes steps such as checking article numbers, creating a storage location, checking additional information, confirming and printing labels etc.

Each item designated for a specific location in stock requires one label, and at least one label is needed for each SKUs or inbound order line. Thus, the activity is driven both by the number of SKUs and the number of labels. It was therefore necessary to create an equation that considered both parameters (see Equation 4). When analyzing the collected data, a value directly related to the process time for each SKU was isolated and an average time of 10 seconds was calculated. Then an additional printing and processing time for each label was identified to be approximately 8 seconds.

$$Total\ time = Number\ of\ SKUs * 10 + Number\ of\ cartons * 8$$

Equation 4. Time for entering information in system

In some cases the operator enters the measured volumes as separate inputs in the system. Therefore, this section has a separate field were the number of volume measures are added to capture this additional time, which is an average value based on observations. If no measures are taken, this field is left empty.

The data in this section does not consider physical movement from sorting area to computer, which can be a time-consuming factor in some cases. For instance, the sorting area at Customer A is located about 50 meters from the station, which means that the operators spend a lot of time walking back and forth between the computer and the goods. In contrast, the distance between computer and goods for Customer C is just a couple of meters. If needed, the time for transport can be added as an additional input if it is considered to have significant impact on the total time for this process.

5.1.8 Wrap pallet in plastic

Some goods might require plastic wrapping before they are placed in stock, e.g. full pallet flows. This can be performed manually by the operator and a roll of plastic or by machine where the operator is observing the process.

The first alternative includes positioning as well as fetching and preparing wrapping material. The automatic alternative considers a positioning distance of approximately two meters, where the operator places the pallet on a platform and starts the machine. Even though the time it takes to manually wrap a pallet is very dependent on individual skills of the operators, it is assumed that this alternative is less time-consuming than using an machine. The machines have a predetermined setting and tend to add substantial amounts of plastics to the pallet regardless if it is required or not.

Furthermore, this section does not include any additional transport distance to the station where the wrapping is performed, which must be noted by the user of the calculation tool.

5.1.9 Label item and prepare for pickup

This activity can be divided into labeling of pallets and separate items. Both alternatives includes the time it takes for one operator to locate the right item and paste the label on it. Furthermore, the activity also includes time for placing them on a trolley or a pallet if it is required. However, this task is not considered to have a significant impact on the total time of the activity.

The complexity of labeling items increases with the number of labels and items, but is also affected by external factors such as congestion at sorting area, placement of pallets and goods, handwriting on cartons etc. Many observations were performed for several different customers in order to get a broad perspective of the activity. The value was provided be recording the whole activity and then divide the elapsed time with the amount of items. One average value was calculated for cartons and one for pallets. Cartons are considered to be less time-consuming to label since these are easier to locate and reach compared to pallets.

The value for this activity only considers physical transportations back and forth between computer and items (or between items) that does not exceed six meters. If additional transport is needed, the user of this calculation tool is recommended to add this as an additional input.

5.1.10 Additional input

In the field “Additional input” in the calculation tool, other time consuming activities can be added if there is any specific customer activities or additional transport distance. Additional inputs can be added at the end of each standard processes, e.g. time for special wrapping, material feeding, inspections and other activities that are not considered in the calculation tool.

5.2 Put away

This subsection will describe and discuss in detail all standard activities for the put away process, from preparation of vehicle to placing the items at their storage locations. All elements included in this process are displayed in Figure 43.

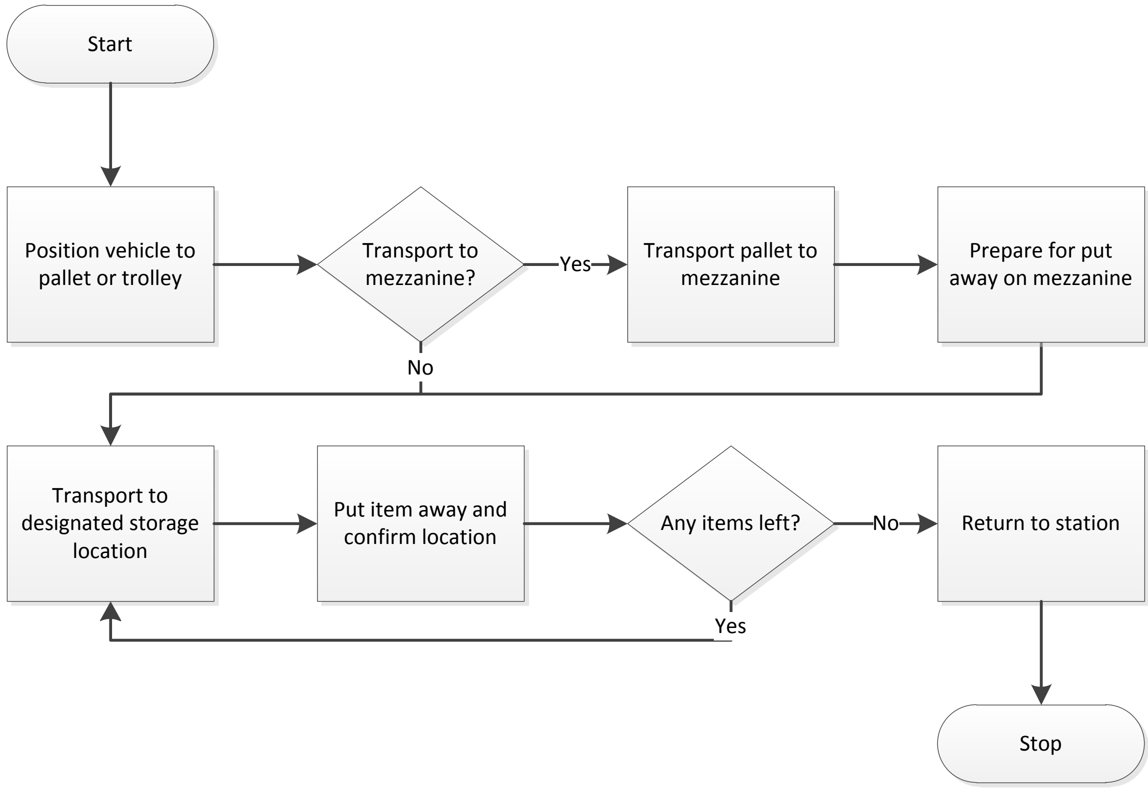


Figure 43. The put away process

5.2.1 Position vehicle and read label

Two alternatives are available for positioning and preparing the vehicle used during put away. The first one considers put away of a full pallet and the time it takes to start the forklift and position it to a full pallet. It also includes the time it takes to collect the pallet and read the item label in order to obtain information about the storage location. This activity is assumed to be performed by a reach truck and the operator starts at a distance of maximum five meters from the pallet.

The other alternative concerns collecting a pallet or trolley with single cartons designated for different storage locations. The transport distance for this alternative is considered to be maximum five meters. This alternative is driven by the amount of cartons on each trolley, since each label needs to be read. However, an average time has been calculated that considers many different situations and customers.

Preparing a route with separate cartons is more time-consuming than for single pallets, since each carton must be handled separately. However, there is a large spread in observed times for this activity between different customers. For instance, when the reading is performed with hand scanners, each label must be scanned and confirmed in the computer, which increases the total time. In contract, Customer C and D do not scan the items before put away, which decreases the time considerably.

5.2.2 Mezzanine transportation

If it is necessary to transport goods to a mezzanine floor from the ground level, it is assumed to be performed by a reach truck. The time for this activity is fixed and includes the time it takes to position a forklift to a pallet and transport it up and. The mezzanine height observed in this study is 6,2 meters and the forklift starts at a distance of 5 meters from lifting position. This activity was recorded and later analyzed to obtain an average time based on three observations, which all resulted in almost identical times.

5.2.3 Transport during put away route

Transport during put away route depends on the type of vehicle used and the average transport distance. When full pallets are transported, each route contains one pallet and can be performed by several alternative vehicles. When separate cartons are transported, the number of cartons for each route needs to be predetermined by the user of the calculation tool in order to get the correct number of routes as input.

This section concerns the distance for completing a full route, i.e. the vehicle starts and ends at the station. The calculation tool builds on the average speed for driving different vehicles, which was provided from the supplier. However, these did not consider acceleration from start position, deceleration, turning around corners, weight and bulkiness of transported goods, individual driver skills, congestions in aisle etc. Thus, the given values were divided by a factor of four to obtain more reliable results after discussions with the tutor at SLOG. It is however difficult to obtain completely accurate values, since much of the variations are related to individual driving skills. However, some of these factors, such as acceleration and deceleration at start and stop locations is included in other sections.

The values given for each type of forklift have been provided by the forklift manufacturer Linde. It is assumed that these values represent the speed of similar forklifts from other brands. A comparison of the different vehicles can be viewed in Figure 44, which displays the adjusted speeds.

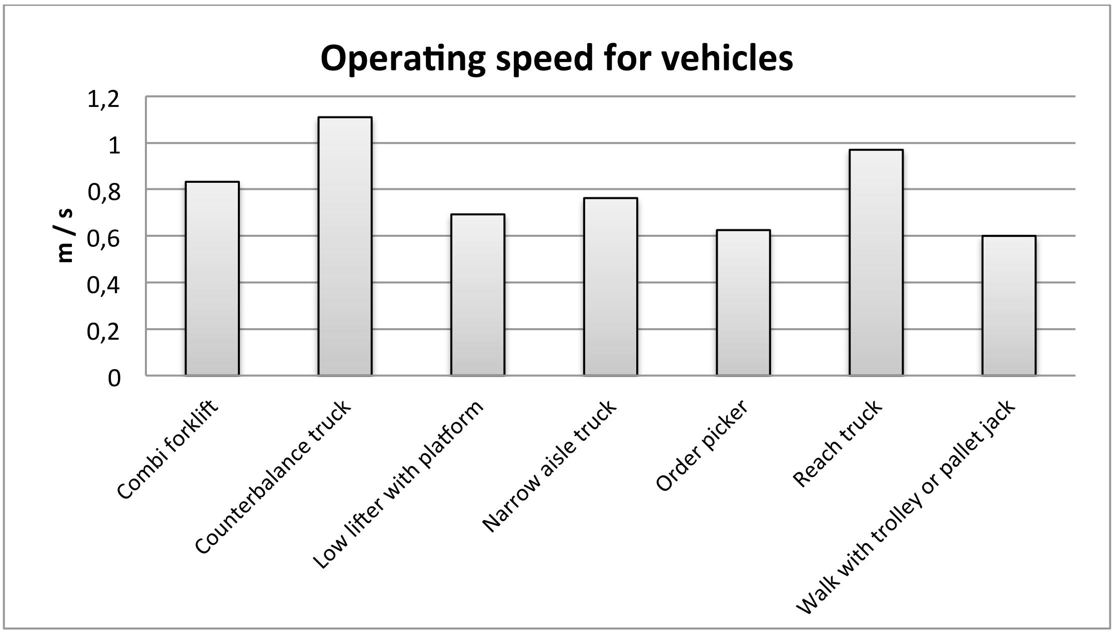


Figure 44. Operating speed for vehicles used by SLOG

The average speed for walking with a trolley has been simulated at a normal walking pace. The simulation was performed in circle along a 20 m long shelf; hence the standard times are based on 40 meters walking, including two turns around corners. The simulation was repeated six times with two different persons and all six recordings resulted in similar times. Based on the leveled time and the distance, an average walking speed was calculated. One assumption is that the average speed of all types of walking is independent of the number of cartons on the trolley or their weight.

5.2.4 Vertical positioning to item location

Vertical positioning to item location is a separate section for put away that cannot be performed by the operator at ground level. It depends on the amount of order lines (i.e. the number of stops along the route) and the average transported height, up and down, in meter and type of vehicle used. The operator must either climb on a ladder or be transported up to the level with the forklift.

When lifting, the forklifts are assumed to operate at full speed during the whole process. The supplier has provided the average speeds for both empty and full loaded lifts and a mean between these has been used in the calculation tool. The values do not consider the fact that the operator can move horizontally simultaneously and hence make the activity more effective in reality. A comparison of the different vehicles can be view in Figure 45.

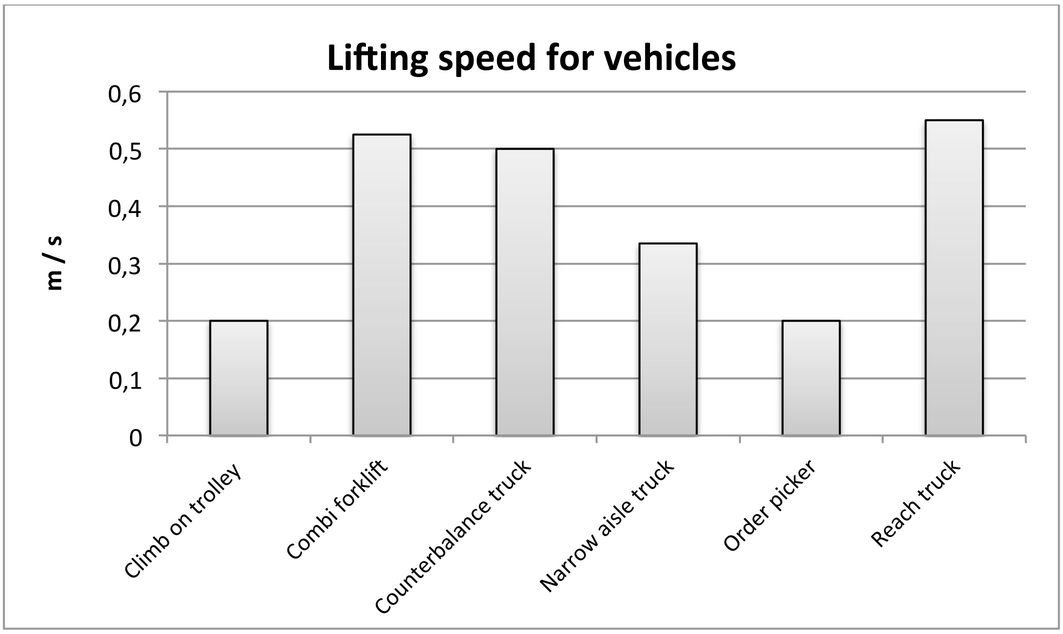


Figure 45. Lifting speed for vehicles used by SLOG

The average speed for climbing on a trolley with ladder has been simulated at a normal climbing pace, without carrying any items. The simulations considered the elapsed time to move vertically from start position to the desired position and by measuring the climbed distance, an average speed could be calculated. Climbing times are individual for each operator and it is difficult to obtain a "normal climbing pace", thus the simulated times may differ in reality. However, not that many customers or solutions apply this type of manual put away of items and when it occurs, the climbing distances are not that large. Thus, individual variations should not have a significant impact on the total time for this process.

5.2.5 Put away item and confirm it

This section considers the activity of placing the item in the storage location. It includes times for decelerating, finding item location, reading label, positioning for put away, placing the item at its location, returning back to original position, confirming put away and start accelerating.

There are two alternatives available in the calculation tool for this section; put away full pallets and put away separate cartons. Pallets are put away by forklifts (either reach truck or combi forklift) and cartons are put away manually from trolley or pallets. The average times do not consider the type of technique used (i.e. hand scanner or list); hence the average value considers situations where both techniques were used.

In general, it takes less time to put away a carton than a pallet. When putting away cartons, the operator is in general at the shelf location and has clear vision of where and how to place them. When handling pallets, the operator is operating the forklift from ground level, which increases the complexity and time for positioning at high levels.

The put away process has no separate section for "order line", that considers the number of stops along the put away route. This can be compared with the picking process where the time for stopping and positioning to item location is considered as an isolated activity, and the actual pick of item as another. A similar distribution was discussed for this section as well in the beginning of the study. However, it was more appropriate to merge these elemental activities together, mainly since the put away activity is often characterized by putting away one single item at each location.

5.2.6 Double cycle

If a double cycle applies, i.e. that the forklift returns with a full pallet and leaves it at the outbound area instead of returning empty, the time for the horizontal transportation in the put away section is reduced by 40 percent. This figure has been estimated after discussion with the tutor at SLOG about situations in other warehouses where the productivity increased significantly after implementation of this concept. It is solely the horizontal transportation that is affected by the double cycle and the calculations are activated in the calculation tool by selecting "yes" in the corresponding drop-down list.

5.3 Picking

This subsection will describe all standard activities for the picking process, from initiating a picking order in the system until the picking route has ended. All elements included in this process are displayed in Figure 46. Some activities are the same as those from section 5.2, e.g. transport during route and vertical positioning to item location. These are therefore not mentioned in this section.

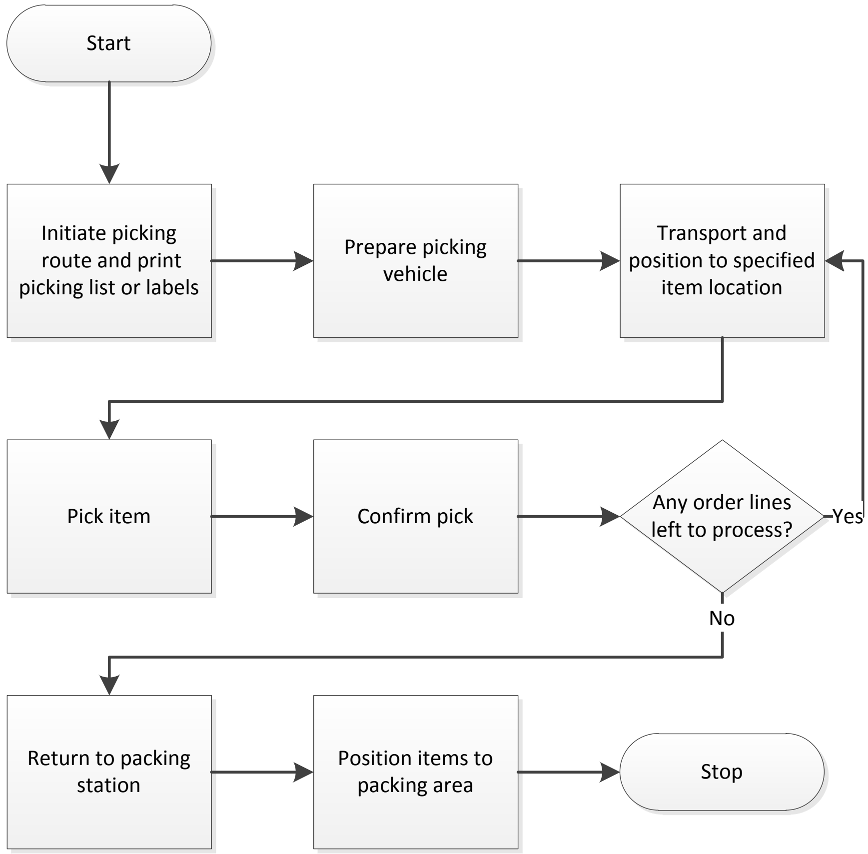


Figure 46. The picking process

5.3.1 Initiate picking

Initiate picking includes the time it takes to print a picking list from the computer or print carrier labels from a printer by initiating an order in the hand scanner. Three alternatives are available that concerns different types of printing. Average times have been calculated for each alternative and are given per picking route.

The first alternative concerns printing a picking list, where the order is initiated in the computer and approximately two pages are printed. The activity starts when the operator enters the system and ends when the list is printed.

The other two alternatives involve initiating orders by hand scanners. The first option is printing several small labels (between two and nine) on one standard paper, which often occur when picking items in totes on a trolley. The other option is printing delivery labels with paste, which is often the case when picking items directly in cartons that do not require any repacking later on. The data for the last alternative are collected from observations where four to eight labels were printed.

The data were collected by observing and recording the required time for operators to initiate an order in the hand scanner or computer, until they held the labels or list in their hands. The collected data were rather homogenous for all three alternatives and observations were made at three different customers; A, B and C. The time deviations that did exist were related mainly to processing times of the different computers and printers. No type of system errors was encountered during the observations and the times are representable during normal circumstances. Therefore, the values do not include any time for maintenance, e.g. for changing ink or refilling paper. These factors might increase the average time for this activity in reality. There were however, no observations of these factors during the study, which make it difficult to assess how they impact the average times.

5.3.2 Prepare picking vehicle

Preparation of picking vehicle includes fetching a forklift or trolley and preparing it with an appropriate number of cartons or totes. Three alternatives are available and an average time for each option has been calculated per route.

Routes with cartons

The first alternative concerns picking routes performed with cartons, where each route requires folding and placing of four to seven cardboard boxes on the vehicle (forklift or trolley). The data in this section is collected from several observations at Customer A, where two different sizes of boxes (small and large) and two different vehicles (trolley and order picker) were used. In reality, the time might differ between the different combinations, however a further breakdown of alternatives in the calculation tool was considered to be too detailed for this study.

This section also assumes a transport distance of approximately 20 meters, since the operator has to move from the computer to collect material, fold it into boxes and place these on the vehicle.

When collecting data for this alternative the operators were asked to prepare cartons. In some cases this task had already been performed at an earlier stage and the operator responsible for picking could simply collect finished cartons. However, in order to get reliable values to the calculation tool it was important that the operators prepared the cartons themselves since this task turned out to be an important time driver for this activity.

The preparation times for this alternative was rather scattered, which can be explained by the varying number of folded cartons. There were, however, some great variations that were not only related to the number of cartons. Other important factors turned out to be the size of the cartons and the individual skills of the operator. In general, a large carton took longer time to fold than a small one. Walking distance when fetching material also affected the activity time. Hence, the number of prepared cartons was not the only significant time driver. Therefore it was more suitable to use an average value for folding four to seven cartons, than to use a specific input for the number of folded cartons.

Routes with totes

The second alternative for this activity is routes performed with totes (i.e. plastic boxes of two different sizes), where these are moved from a pile or stock and placed on the vehicle. The observations for this section were made at Customer B, where the operators have to walk from the printer to the location where the boxes are stored, a distance of approximately 15 meters.

In general, nine totes are used for each route since this is the most common amount for this alternative. Data for this alternative show less variation than for the first alternative, which can be related to the fact that there are no cartons to fold or prepare. The activity itself is more standardized with fewer tasks, which consequently result in more homogenous times even though several different operators were observed.

Routes with pallets or trolleys

The third and last alternative involves routes where items are placed straight on a pallet or on a trolley without any preparation of cartons or boxes. This is for instance often the case when picking by list or in very narrow aisles. This time includes collecting the lists, sorting and attaching them on the truck and fetching a pallet or trolley (if needed). The data in this section considers a transport distance for the operator of approximately 10 meters. The scattering of the collected data for the last alternative showed the least variation of all three alternatives. It is also the least time-consuming option.

5.3.3 Order line / number of stops

This section considers all the stops for picking along the route and associated activities before and after picking the item. Before picking, it includes the time for deceleration, finding item location and positioning for picking. In reality, some of these tasks can be performed during the vertical positioning, however in the calculation tool it is assumed that they occur afterwards.

Furthermore, the order line section occasionally includes additional times for opening up boxes and collecting empty cartons. These tasks occur more or less frequently for all customers and have been observed during all studies. Therefore, it is important to include these as standard elements in this activity.

Elements that occur after the item is placed on the vehicle are also included in this section, e.g. scanning of box or checking of list, returning back to original position and accelerating to next location.

Several factors impact the time it takes to process an order line, e.g. the type of picking technique (hand scanner or list), aisle (wide or narrow aisle), storage solution (pallet racking or shelves), vehicle, placing of items, individual skills of the operators etc. Different combinations have been studied and these are available for selection in the calculation tool, where average times are used for each alternative (see Figure 47). The combinations available for this section are:

- Pick by list, shelves in wide aisle
- Pick by list, shelves in very narrow aisle
- Pick by list, racks in wide aisle
- Pick by list, racks in very narrow aisle
- Hand scanner, shelves in wide aisle
- Hand scanner, low shelves
- Hand scanner, racks in wide aisle
- Pick pallet in wide aisle

Data from nine different picking procedures has been collected by video recording. It was necessary to record and analyze the activity in a video editing software since the activity occurs very rapidly and often overlaps with other activities. The order line consists of all elemental times related to positioning and locating the item, while the actual picking procedure is isolated from this activity. The picking activity should only depend on the weight and the depth of the pick, hence it was important to isolate this completely from the order line section. The video recordings were often analyzed twice to ensure the accuracy of the obtained values.

The time deviations between the alternatives are assumed to be mainly related to the combination of aisles, picking techniques and vehicle used. It takes longer time to position the vehicle in a wide aisle than in a narrow aisle. The walking distance will also increase in wide aisle, which increases the average times. Another significant time driver is the task to open up sealed boxes and collect empty cartons and place them on the vehicle. This was confirmed both by interviewing operators and analyzing the collected data. Gathering cartons and opening boxes have subsequently increased the average times for this section.

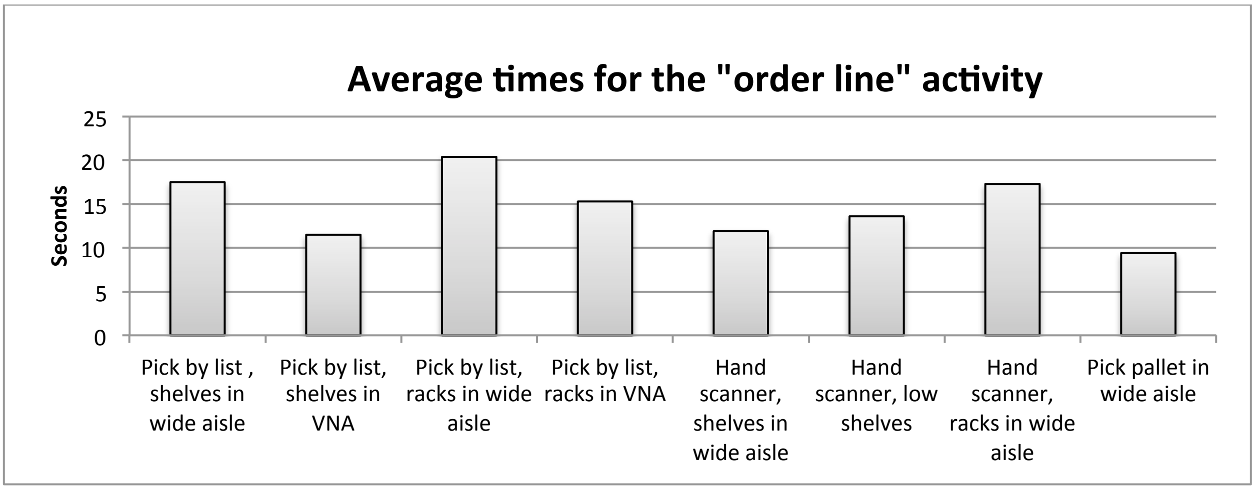


Figure 47. Average times for different alternatives for "order line / number of stops"

The values for "pick by list, shelves in wide aisle" are obtained from Customer C. The picking procedure is performed with a low-level order picker in wide aisles. During observations, there were few boxes that needed to be opened and a limited amount of empty boxes had to be collected. However, the operator had to check the list to make sure that the batch number (as well as the article number) was correct, which increases the average time.

For the option "pick by list, shelves in very narrow aisle", Customer B and D have contributed with data. The picking procedure was performed with narrow aisle trucks from shelves containing small boxes. Observations for both customers showed rather similar patterns with few interruptions of opening up sealed boxes or collecting empty boxes. The option "pick by list, racks in very narrow aisle" showed similar results, but instead of small boxes on shelves the material had to be retrieved from cartons placed on pallets. Hence the items were somewhat more difficult to positioning to and consequently the average time for this alternative is slightly higher. The values for this option were obtained only from Customer D.

The times for "pick by list, racks in wide aisle" are gathered at the zone for bulky goods at Customer A. The items were picked mainly from large plywood boxes on ground levels with a low-level order picker. Occasionally it was necessary to open up new plywood boxes, which required additional time and consequently increased the average times for this activity. Furthermore, the operators had to read the marks on the floor to make sure that they were at the right location, which increases the time for this alternative in comparison with other alternatives.

The values for "hand scanner, shelves in wide aisle" were obtained in the zone for flow racks at Customer A, with trolleys. Some additional time was spent on opening up new boxes and collecting empty ones, but these elements were less frequently compared to for instance the option "hand scanner, racks in wide aisle".

The average times for "hand scanner, low shelves" are obtained from observations on the mezzanine floor for Customer B. The picking is performed with a trolley in narrow aisles with low shelves. The cartons at Customer B have covers that need to be removed before the items can be picked, which consequently increases the time. On the other hand, the cartons do not require similar time-consuming opening procedures as for many other customers. In addition, picking in low shelves is affected by the limited space between the boxes and the shelves. During the time studies there were no observations of throwing away of empty cartons. This is however a frequently occurring task at Customer B, which may subsequently increase the activity time in reality.

For the option "hand scanner, racks in wide aisle" the data was collected from two zones at Customer A; shoes and pallet 1&2. Both zones concerns picking with a low-level order-picker from racks with pallets containing cartons with varies sizes. The zones are characterized with frequently occurring elements of opening up new boxes and throwing away empty ones. The items are relatively large in this zone, and it is often difficult to make them fit in the boxes on the forklift. This is one explanation to the increased average times for this alternative.

The last alternative is "pick pallet in wide aisle" and it concern picking of pallets with a high reach truck. The time measured is the time it takes to slow down and place the forks in a position ready to grasp the pallet, as well as the time it takes to accelerate once more after the pallet is picked. No vertical movements are included in this section, even though it is possible to perform these activities simultaneously. The values for this alternative is obtained from video recordings at Customer C.

5.3.4 Pick pallet or item

Picking can be performed in two ways; either picking of a full pallet or separate items. Picking a single pallet is performed with a reach truck or a combi forklift and an average time for this activity has been calculated. This activity starts when the forks start moving until they are back at their original position with the pallet. The data for this section was collected from two different customers, and the values were very homogenous.

Picking single items considers the time it takes from when the operator is ready to reach for the item. The activity ends when the item is placed on the vehicle. One pick concerns one move, which in turn can include several items. It does not consider any additional horizontal or vertical movement, or any tasks that includes the hand scanner or list, opening up sealed boxes etc., since these elements are already included in the order line section. Hence, this activity is assumed to depend only on the depth of the pick location and the average weight of the pick.

The calculation tool builds on simulated data that cover a wide range of depths and weights. The simulation has been performed with items ranging from 0 -15 kg in weight and pick depths ranging from 300 mm to 1200 mm. The average values from the simulations can be viewed in Table 2.

	Weight (kg)						
Depth (mm)	0 < w≤ 0,5	0,5<w≤ 1	1 <w ≤ 3	3 < w ≤ 5	5 < w ≤ 10	10< w≤ 15	w < 15
300	2,6	3	4,1	4,4	4,4	4,8	7,9
600	3,3	3,7	4,6	5	5,2	5,2	8,6
800	4,2	4,8	5,3	5,9	6,1	6,5	10,6
1200	5,1	5,8	5,9	6,7	6,9	7,7	12,7

Table 2. Simulated times for picking different items from different depths

The user of the calculation tool enters the average weight of the item and depth, and the model return a value from this matrix that represent these inputs. The items used in the simulation were easy to grasp with one or two hands. Hence, the values are not representative for large and bulky items. The simulated picking times were compared and validated with observed picking times.

5.3.5 Position items to packing area

This section considers the activity of positioning picked items from the trolley or forklift to the table or to a fixed position at packing station. An average time has been calculated per box and the collected data covers a transport distance of maximum 3 meters back and forth between vehicle and packing area. The time starts when the operator grabs the box or items and ends when the operator is back at starting position. The collected data for this activity was rather standardized and the deviations that did exist were mostly related to walking distances.

If the route has been performed with a pallet without any boxes or totes, the time in this section only considers the time it takes to position the pallet to the packing station by the forklift, a distance of maximum 6 meters. This alternative is somewhat more time-consuming than the first one.

5.4 Packing

This subsection describes all standard activities for the packing process, from initiating packing until loading of goods on a vehicle. In those cases where items are placed directly in their boxes (with attached delivery label) during the picking process, only the sections starting from “Seal and add label” needs to be considered. All elements included in the process are displayed in Figure 48. Some activities are the same as those from section 5.1 and 5.2, e.g. transport from mezzanine and wrap pallet in plastic. These are therefore not mentioned in this section.

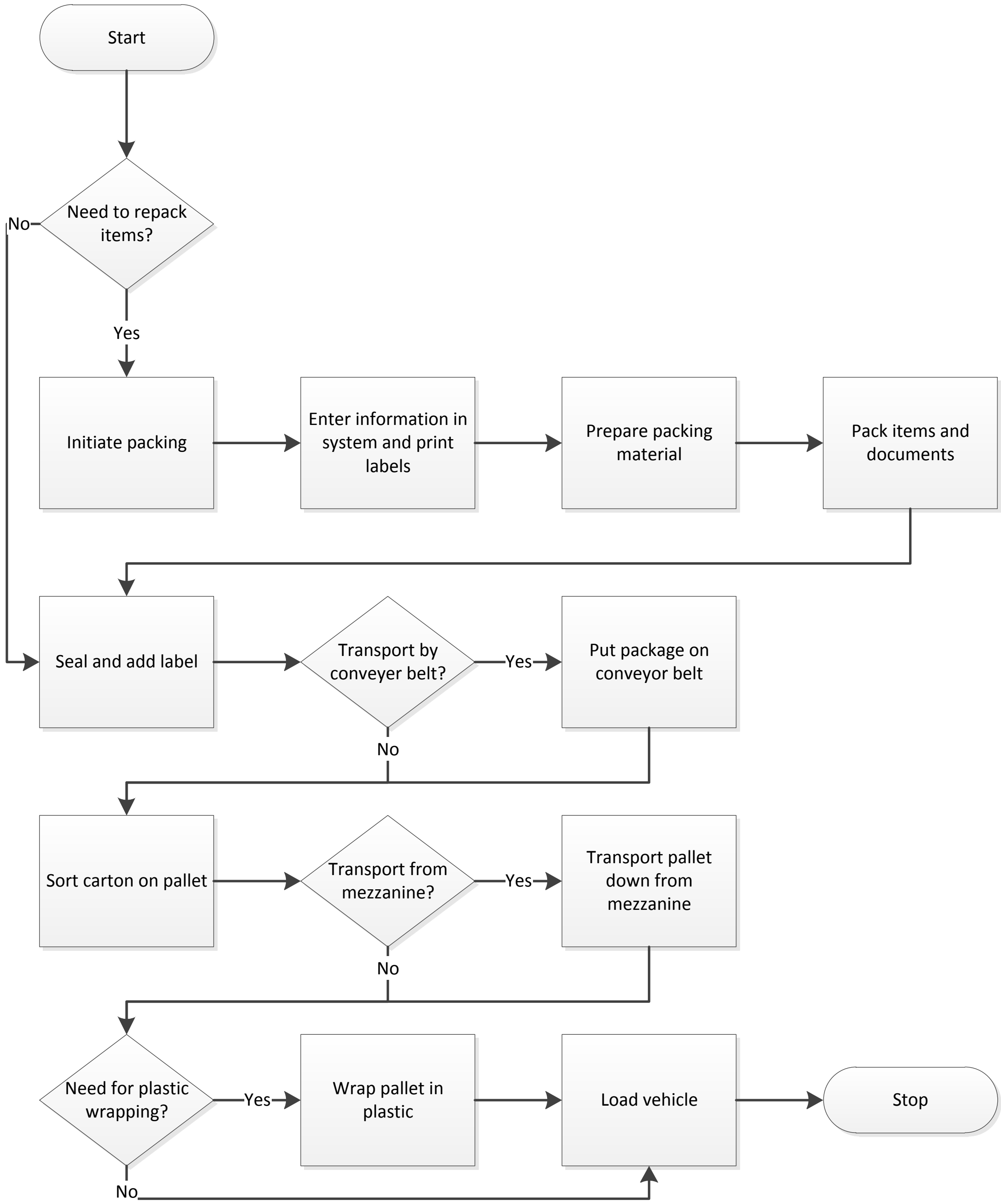


Figure 48. The packing process

5.4.1 Initiate packing

Initiate packing considers the time it takes to collect items from the positions where the picking operator left them, and place them on a packing table where they await packing. The time for this activity starts when the operator reaches out to grab the items and ends when they are ready for processing. The data in this section only concerns one move to the table, which can includes several items depending on their sizes. The data collection for this section originates mainly from Customer B and C.

The time is assumed to be driven only by the type of picking technique involved. If a hand scanner is used, the activity ends when the barcode of a carrier is scanned, which makes information about the order available in the system. Thus, the operator does not need to do any manual control of article numbers before start packing. If a list is used, some additional time is spent on checking the article number to make sure that the operator has picked the right items. Therefore, the time for initiating packing with list is somewhat longer than for hand scanners, which is supported by the collected data.

This section is left empty if the items have been placed in their outbound boxes directly during the picking process.

5.4.2 Enter information in the system

Enter information in system includes the time it takes to create a delivery and print labels and documents. The activity starts when the operator enters the system and ends when all documents are printed. The time is assumed to be fixed per customer order and each order is assumed to require only one package and one label. Thus, it was not important to use the same type of division of time drivers as in the corresponding activity in the reception process. Furthermore, the collected data showed no differences between different picking techniques, hence the activity is independent of this factor.

This time is mainly driven by the processing time of the system and printer, and different types of printers have varying processing times. The data in this section only considers the actual system time and it is assumed that no other tasks are performed during this activity. In some cases, additional tasks can be performed while waiting for the printer, e.g. preparation of material or packing. However, these tasks are not included in this section in the calculation tool.

The actual processing time represents a substantial time for this activity. As stated earlier, the operator can choose to wait or perform other tasks while the documents are printed. During the observations, it was clear that the overall time for the packing process decreased when the operator performed other tasks during the activity. However, not all operators choose to work this way and it was therefore important to observe many different operators to obtain a broad set data that considers many different working techniques.

For some customer solutions (e.g. Customer C), the labels can be printed all at once after a picking route is finished, which results in a lower time for each order in reality. However, the data in this section only concerns situations where one order is processed at a time.

This section is left empty if the items have been placed in their outbound boxes directly during the picking process.

5.4.3 Prepare packing material

Preparation of packing material concerns collecting and folding material into appropriate shapes. There are two different kinds of packing material available in this study: cartons and letters. The preparation for letters does not require any folding and the data in this section concerns plastic and padded letters. Several different types of cartons are available and the collected data mostly concern situations where small and medium sized packages were prepared. The activity starts when the operator touches the material and ends when the box or letter is finished and ready for packing.

As expected, the data showed that activity times for cartons were considerably longer than for letters. The calculation tool does not take into consideration the many different sizes and models of cartons that are available. Instead, an average time has been calculated in order to consider different sizes and shapes of cartons.

The data in this section builds on situations where the packing material is located at the packing station, where no additional transport or movement is necessary in order to collect the material. For instance, under normal circumstances the operators at Customer B estimate that they need to replenish material approximately two times every hour. These times are considered as additional inputs and are not included in the standard time for this activity.

This section is left empty if the items have been placed in their outbound boxes directly during the picking process.

5.4.4 Pack item

Packing of cartons or letters is independent of the amount of items, as long as the items can be transferred to the box or letter in one move. The activity starts when the operator touches the items and ends when the last item is placed in the carton or letter. This section also considers isolated events such as adding documents, plastic bubbles or packing paper to the box, as long as this is performed in one separate move. It can be difficult to estimate how many articles an operator can process in one move and how many moves that are required. This is often related to the size and weight of the articles, which must be estimated by the user of the calculation tool.

An assumption is that there is no difference in time between placing items in a letter and a cardboard box, which is supported by the collected data. This section is left empty if the items have been placed in their outbound carriers directly during the picking process.

5.4.5 Seal and add label

Seal and add label to a box or letter is performed after the last item is placed in the package and the activity ends when it is sealed and ready for sorting. Four different alternatives are available in this section: seal carton with tape, seal carton with plastic strap (performed by a machine), seal letter by pasting it and just add a label to an already sealed package. The collected data showed distinct differences between the four alternatives and average times were calculated for each alternative (see Figure 49).

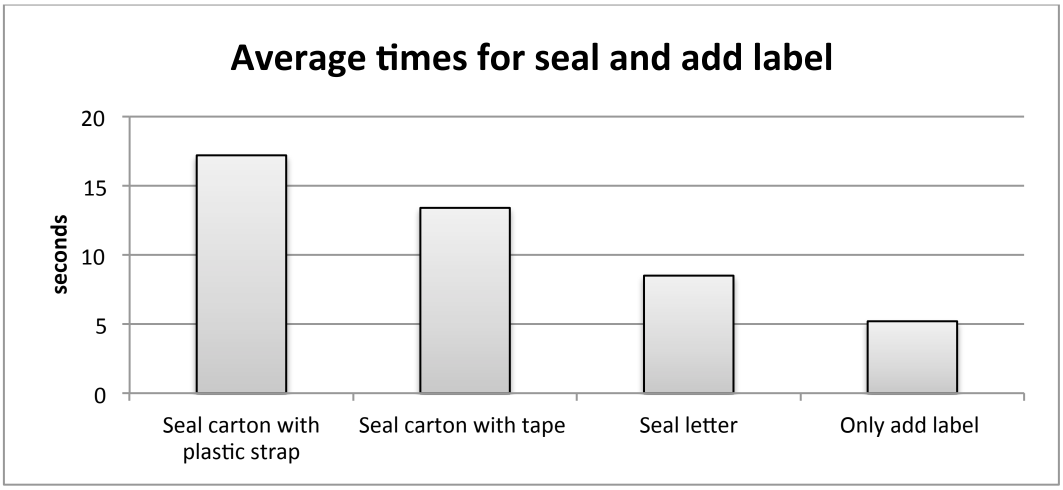


Figure 49. Average times for seal and add label

Sealing cartons with plastic strap can be performed either with one or two straps and an average value that considers both options have been calculated.

When observing situations where cartons were sealed with tape, it was clear that the time is highly correlated with the amount of tape used and the efficiency of the operator. According to the operators, the size of the carton is not a significant time driver. Some of the collected data concerns situations where the operator needed to change the tape roller etc. These are frequent element in this activity and are therefore important to consider in the standard times.

An assumption before performing the observations was that sealing letters and just add a label to an already sealed carton are significant less time-consuming than the first two alternatives. This was supported by the collected data.

5.4.6 Put package on conveyer belt

In cases where the packing station is located far from the outbound area and transport is performed by a conveyer belt, as in the case of Customer B, there is an additional activity of placing the boxes on the conveyer. This section is also representable for the time it takes to sort letters or small boxes in totes before they are put on pallets or in cages where they await pick up, which is often the case at Customer D.

This activity does only consider body movement from the packing station to the conveyer belt, and no additional walking distance. The collected data turned out to be very homogenous and only a few recordings were needed in order to obtain reliable average times.

5.4.7 Sort package on pallet

The time it takes to sort a letter or box on a pallet is assumed to be fixed per package. The activity starts when the operator grabs the carton or box and ends when the operator is back at the original position. It is assumed that the pallets are positioned in a way that will minimize the walking distance and in no observation this distance was over 10 meters. Hence, if the distance back and forth exceeds 10 meters it might be necessary to add an additional walking time.

Furthermore, this activity is assumed to be independent of the weights and shapes of the boxes or letters, as well as the number of pallets at the outbound area. However, the collected data showed great scatters, ranging from 3 up to 30 seconds. This means that other factors impact the activity in reality such as distance, number of pallets, size and weight of the item and the operator's working speed. Another finding was that some operators worked at a lower speed when they were unaware of the observers. Thus, it was important to calculate an average that considers many different operators, packages and situations.

5.4.8 Load vehicle

This section considers the activity of transporting goods loaded on a pallet, from the sorting or outbound area, to the loading dock until it is placed inside the truck. In reality, the time it takes to perform this is dependent on the transported distance, type of vehicle and how the pallets are stacked. However, an assumption for the calculation tool is that the loading is the reversed procedure of the activity unloading pallets from a truck. Thus, the data is taken from the corresponding section for unloading a truck with pallets.

An average value has been calculated to consider situations where both pallet jacks and low lifters with platforms are used. An assumption is that the distance does not exceed 20 meters and if the loading is done by a third part, this section is left empty.

5.5 Layout of calculation tool

Based on the standard activities presented in the sections above a calculation tool in Excel was developed. The calculation tool consists of the following six sheets in the Excel document: Summary, Process design, Data, Process description, Definitions and Manning.

The data sheet contains all standard times that have been obtained from the time studies. It also contains values for the different drop-down lists and a matrix with values for the picking activity. The sheet for process descriptions contains brief descriptions of what is included in each activity. The start and stop event for each activity is defined and relevant notes are added with information regarding distances and other inputs useful for the user of the tool. There is also a definition sheet where all the abbreviations and definitions are explained. The sheet called manning will facilitate calculations of the required number of full time employees (FTE) as well as the number of temporarily employees. The manning calculations also consider seasonal variations and the manning cost for each month, as well as for a full year.

In the summary sheet there is a breakdown of the different sections in the calculation tool (see Figure 50 below). The summary sheet collects data from the Process design sheet and the total times in hours for the corresponding sections are displayed in the rightmost column. In the row with time allowances it is possible to choose the size of customer and complexity of the processes. Depending on the selections, a specific PF&D time value in percentage will be obtained. This percentage is added to the required need, which results in a total need that also considers different time allowances. In the next-coming section 5.6 there is a more thorough discussion about the different allowances and how these were obtained. The summary sheet also displays the number of full time employees required to fulfill the need.

Overall manual labor need per year	
Reception hours	X
Put away hours	X
Total time inbound	X
Picking hours	X
Packing hours	X
Total time outbound	X
Total required need	X
Time allowances **Large customer:** Yes **Complex processes:** Yes X %	X
Total FTE / day (incl. allowances)	X
Total need / year (incl. allowances)	X

Figure 50. Calculation tool - Summary

The next sheet in is the Process design where customer specific inputs for the calculations are entered. As explained earlier, the calculation tool consists of four different sections: Reception, Put away, Picking and Packing. These are all displayed in the upcoming figures 51 - 54. The principle is the same for all processes: the specific customer data is entered in the input column and the tool will retrieve data from the data sheet and calculate a time in seconds, respectively hours. The shaded areas in the Process design sheet are drop-down lists with multiple alternatives, each resulting in different values.

Process design

Reception	Input	Unit	Time seconds		Time hours		Comments
1. Prepare unloading							
No. of container or truck deliveries		deliveries	0	s	0,0	h	
No. of courier deliveries		deliveries	0	s	0,0	h	
2. Unload cartons from vehicle							
Type of loading							
Unloading method							
No. of SKU/vehicle		SKUs					
No. of cartons/vehicle		cartons					
No of carton		cartons	0	s	0,0	h	
Unload full pallets from vehicle							
Type of forklift							
No of pallets		pallets	0	s	0,0	h	
Total time			0	s	0,0	h	
3. Sort unsorted goods							
No. of cartons		cartons	0	s	0,0	h	
No. of mixed cartons		cartons	0	s	0,0	h	
4. Verification							
No. of cartons		cartons	0	s	0,0	h	
5. Volume control and calculation							
No. of samples		samples	0	s	0,0	h	
6. Product control							
No. of samples		samples	0	s	0,0	h	
7. Enter information in system							
No. of labels/year		labels					
No of SKUs/year		SKUs	0	s	0,0	h	
No. of volumes added in system		order lines	0	s	0,0	h	
Total time			0	s	0	h	
8. Wrap pallet in plastic							
Wrapping technique							
No. of pallets		pallets	0	s	0,0	h	
9. Label item and prepare for pick up							
No. of pallets		pallets	0	s	0,0	h	
No. of cartons		cartons	0	s	0,0	h	
10. Additional inputs							
Additional inputs		seconds	0	s	0,0	h	
Total time reception			0	s	0,0	h	

Figure 51. The calculation tool - reception

Put away	Input	Unit	Time seconds		Time hours		Comments
1. Position vehicle and read label							
No. of routes with full pallets		routes	0	s	0,0	h	
No. of routes with separate cartons		routes	0	s	0,0	h	
2. Transport to mezzanine floor							
No. of pallets		pallets	0	s	0,0	h	
3. Transport during put away							
Alt. 1							
Type of transportation							
Number of routes		routes					
Average transport distance per route		m	0	s	0,0	h	
Alt. 2							
Type of transportation							
Number of routes		routes					
Average transport distance per route		m	0	s	0,0	h	
Alt. 3							
Type of transportation							
Number of 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							
Alt. 1							
Type of transportation							
No. of inbound order lines		order lines					
Average positioning height (up and down)		m	0	s	0,0	h	
Alt. 2							
Type of transportation							
No. of inbound order lines		order lines					
Average positioning height (up and down)		m	0	s	0,0	h	
Alt. 3							
Type of transportation							
No. of inbound order lines		order lines					
Average positioning height (up and down)		m	0	s	0,0	h	
Total time			0	s	0,0	h	
5. Put away item and confirm							
No. of cartons		cartons	0	s	0,0	h	
No. of pallets		pallets	0	s	0,0	h	
6. Double cycle							
Double cycle possible?			0	s	0,0	h	
7. Additional inputs							
Additional inputs			0	s	0,0	h	
Total time put away			0	s	0,0	h	

Figure 52. The calculation tool - put away

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	

Figure 53. The calculation tool - picking

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	

Figure 54. The calculation tool – packing

There is also a consolidated version of the process design sheet. It is possible to group sections and activities together and by that concealing them when they are not in use. This makes it more convenient for the user to navigate between different sections and activities.

5.6 Validation and calculation of time allowances

One very important part of the purpose of the thesis is the determination of solution specific time allowances that are added to the required times generated by the calculation tool. In order to estimate the appropriate percentages for different customers, it was important to consider both the size of the customer and the complexity of the operations. Therefore, the tool was tested with data from the observed customers. In addition, the aim with the tests was to evaluate the accuracy of the collected data and validate the assumptions and programming behind the calculation tool.

Data to validate the model was first provided by the IT Department at SLL. Raw data from databases of the WMS were processed in Excel and customer specific inputs were extracted and added in the model. This was performed to obtain the required time for fulfilling the specific need, i.e. no time allowances for personal, fatigue and other delays were included in the generated output. The results were compared with the reported working hours for the operators during the same time period. Initially, data on a yearly basis was tested, which was appropriate for a small customer like Customer C with relatively low volumes and amounts of data. However, the database files for other customers, such as Customer A, were too complex to process in Excel, which made it difficult to extract the necessary information. Hence it was not possible to base the initial tests on yearly data without breaking it down to a weekly basis.

Customer C was the first customer that was tested with this approach, using data on a year basis. As expected, the result in generated hours was significantly lower than the actual values. However, the difference was far greater than anticipated, with deviations of several 100 percent for both inbound and outbound processes. This was neither a credible nor a satisfying result. The same approach was used when testing data from Customer A and similar results with significant deviations was obtain as well, although not as large as for Customer C.

All factors concerning the different processes in the calculation tool were analyzed and questioned in order to find out if any values were underestimated or misjudged. No obvious problems were found in the programming of the tool or in the collected data. Instead the input data extracted from the databases and WMS was evaluated and its credibility was discussed. Since the researches were unfamiliar with the structure of the databases and had the responsibility of extracting and choosing all input data, it was difficult to know exactly which data was belonging to what activity. The databases contained extensive amounts of data, which increased the complexity of this task. Thus, some of the deviations in the initial validation approach could be explained by uncertainties in the selection of input data.

Furthermore, the only way to obtain actual manning hours in the initial testing phase was to look at the reported hours for the operators. These were often divided into hours spent on either inbound, outbound, VAS, teaching, handling claims etc., and looked very different for the different customers. When testing the model, only the hours for inbound and outbound activities were considered. It was not clarified how much time the operators spent on the different processes (i.e. reception, put away, picking and packing) for these main sections. Besides, it is possible that the reported hours by the operators are deviating from the reality since operators could have forgotten to check in/out or change working zone in the system.

Considering the great deviations in the prior method, a new approach was used to test the calculation tool. Together with the tutor and other employees at Solution Design at SLOG, data inputs were gathered from RFQ data sets developed for the different customers. The volumes were also compared and validated with real data given by the production monitor (which represent the interface between the WMS and the time reporting system.) The generated output was then compared with both invoiced hours and reported working hours by the operators, as well as the outputs generated by SLOG's current calculation tool.

This difference between the generated output and the actual working hours corresponds to the additional time that needs to be added in order to consider personal, fatigue and other delays described in section 2.2.4. Furthermore, the time differences at SLOG is assumed to have a large connection to the size of the customers and complexity of the operations. For instance, if the order volumes and amount of work are low and the operators are spending time on waiting on assignments, the difference between the required and actual time increases. In addition, if the complexity of the operation (e.g. customized activities, VAS, need for handling deviations and other irregular elements) increases, so does the time difference. This means that the percentage for other delays in the case of SLOG is larger than the theoretical estimations, which will increase the overall PF&D time allowances compared those estimated by theory.

Figure 55 displays the relations between the observed customers with regard to their size and complexity of operations. It is a very simplified interpretation based on observations and discussions, but it is assumed to be a suitable guideline when determining the appropriate allowance level.

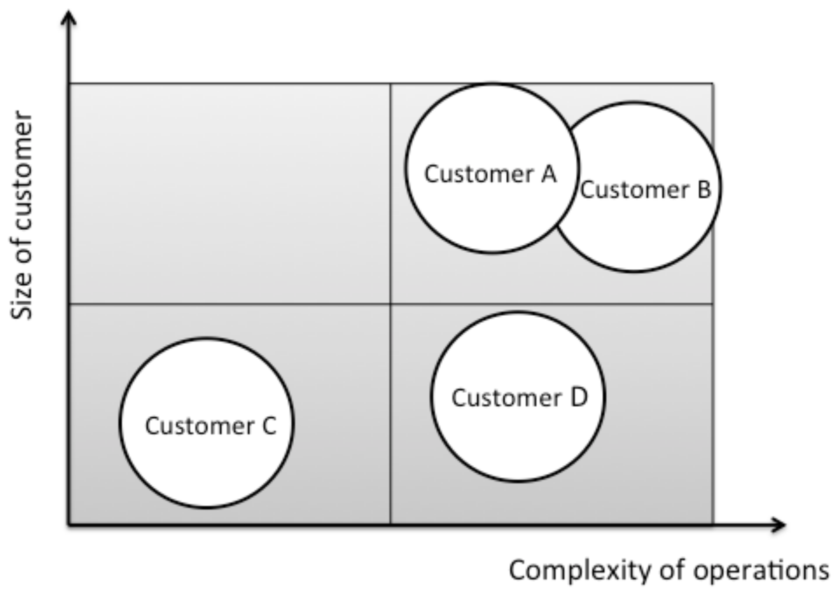


Figure 55. The simplified relations between customers regarding size and complexity

The first customer that was tested with the new approach was Customer A and data used for the validation was representing the demand of one week. The calculated difference for this customer was about 50 percent when considering the total required need for both inbound and outbound processes. Customer A is considered as a large customer with complex processes. Hence it is necessary to add 50 % of the generated times in order to obtain the total time it take to perform the activities.

When performing similar tests for Customer B, the demand for one year was used as basis. The results were almost identical to those of Customer A, with time differences of about 50 percent for both inbound and outbound processes. Customer B is also considered as a large customer with complex processes.

Customer C is the smallest customer with a low degree of complexity, resulting in time differences of 80 percent. Due to its size, the allowances were assumed to be greater than the other three customers. The operators at Customer C often have fewer volumes to process and must sometimes await new orders, which increases the non-value adding time. The data for Customer C considered the demand for one year.

Customer D is also a small customer (however, somewhat larger than Customer C) with complex processes and the calculated differences turned out to be 60 percent when using data for one year. This is a slightly higher figure than for Customer A and B, which can be partly explained by the size of Customer D's operations. This figure might be somewhat contradictory in comparison to Customer C, since complex operations would increase the time differences. However, it is difficult to predict which factor (i.e. size or complexity) has the largest impact on time. Thus, 60 percent represents the initial value that needs to be investigated further to prove its accuracy.

The only combination of size and complexity that could not be assessed at SLL was large customers with less complex processes. These are often the features of the warehouse solutions for customers producing food, wine and other rapid-turnover consumer good. The complexity of these solutions is considered to be rather low since they are handling full pallet flows, not many claims or returns or other interruptions. SLOG is currently handling one customer with these characteristics in their DC at Arlanda. However, data from this customer were not available for validation at this point in time. Thus, to facilitate the completion of the calculation tool, an estimated value of 30 percent for this type of combination was set after discussions with the tutor at SLOG. This value is assumed to be representable for at least the customer in Arlanda, but the calculation tools needs to be tested with customer specific input in order to prove the validity.

5.7 Quality of study and calculation tool

After discussion with employees at Solution Design at SLOG, the results were assessed as realistic and representative for the different type of customers at SLL. However, the variances and sizes of the PF&D time allowances for the different customers turned out to be larger than anticipated. Below, five factors are discussed that are especially prominent for the results.

Firstly, the average times for different activities in the calculation model are representative for an isolated task. Hence, there are no additional transport distances included (if not stated in the activity description) and no slack time between tasks. Since it is no line-production in the warehouse it can be difficult to be constantly active and only perform value-adding activities. Furthermore, most time measurement studies presented in prior research focuses on studies with highly repetitive and standardized tasks. This is not the case for the warehouse operations of SLL, resulting in higher variances and thus increased uncertainties in the observed times.

Secondly, some activities are excluded from the calculation tool. One of these are replenishment of materials at the packing stations. Hence, the time spent on this activity will increase the required process time in reality and thus the time differences. Another activity outside the scope of the tool is replenishment orders. These are often easy to isolate when determining the input data to test the model, and should therefore not impact the results. However, the actual working hours for this activity can be more difficult to isolate since the operator often report this activity as either "inbound" or "outbound" in the system. Thus, some of the differences in the results can be explained by this. Furthermore, there is always a possibility that the operators have forgotten to the change task when reporting the time, resulting in non-representative time distributions between activities. Other activities that were excluded from the calculation model were VAS-activities and education of new employees, however these are easier to isolate than the replenishment activities.

Thirdly, the model is a simplified version of the reality, which means that it cannot consider customer specific deviations or other undefined factors that increase the complexity of the operators. Deviations that require additional time will increase the overall process time and thus the gap between the required and invoiced hours.

Fourthly, the generated times are standard times for activities collected from mainly four different customers. Many of these values have been aggregated to represent different situations, but in reality there might be additional solutions that are not covered by the calculation tool and must therefore be estimated manually.

Finally, there are always deviations between operators based on individuality such as skills and working pace. One important factor during the time recordings was the use of qualified operators working at normal effort in order to get the required time to perform the task. Thus, the assumption was that the operators were performing at average efforts all the time and did not have any incentives to work at dedicated effort. However, during the observation it became clear that some operators were increasing their speed and effort. Therefore, it cannot be assumed that all data concerns average efforts. Some deviations between the generated values and reality can be explained by differences between average and dedicated efforts, and the required time might need to be adjusted accordingly.

6 Recommendations

This section provides some useful inputs regarding the PF&D allowances and the use of the calculation tool. The section will also highlight problems and inefficiencies in the inbound and outbound processes at SLL and discusses potential improvements.

6.1 Use of calculation tool

The user of the calculation tool is recommended to consider the assumptions and limitations presented in section 5 before use, in order to gain understanding of the different sections and the required input data. The better knowledge of the underlying conditions, the more accurate results are expected to be generated by the calculation tool. One recommendation is to make a clear distinction between input data such as order lines, number of routes, number of cartons, number of packages etc. A shorter version of the assumptions and the process descriptions are available in the Excel-based calculation tool, in the sheet "Process descriptions".

The final step for determining the amount of blue-collar labor in the calculation tool is to estimate the PF&D time allowances for the specific solution design. As discussed in the analysis, the calculation tool is validated and tested on four different types of customers; two large customers with complex processes, one small customer with complex processes and finally a small customer with less degree of complexity. Figure 56 represents the PF&D time allowances in percentage used for the customers in this study. The numbers represents the amount of additional time that is recommended to be added to the required hours in order to obtain values that are as accurate and similar to reality as possible.

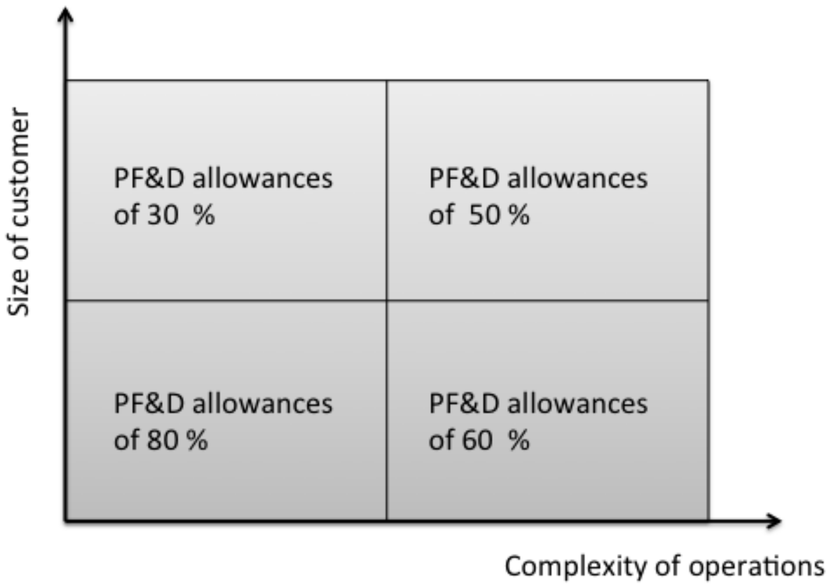


Figure 56. The estimated PF&D time allowances in percentage based on size and complexity

These percentages should be used as a general guideline when determining the PF&D allowances for new solutions that are similar to the observed customer. The estimated allowances with regard to the size and complexity contain a certain degree of uncertainty, which can be mitigated by further tests of the calculation tool. Furthermore, these values can easily be updated when new data is available for validation and SLOG is recommended to update these as soon as it is possible.

SLOG is not only recommended to use the calculation model in the quoting process, but also for evaluating the current productivity for different solution design. This can facilitate the understanding of different time drivers and bottlenecks in present processes and act as foundation for improvements, which is in line with SLOG's ambition to lower the total cost of logistics for their customer and focus on high process efficiency.

6.2 General recommendations

This section seeks to point out the main problems and inefficiencies in the inbound and outbound processes at SLL, recognized by employees and the researches during the study. These and potential improvements will be discussed both in general and in the case of specific customers.

Decrease transport distances - One of the issues in the reception process turned out to be the transport distance between packing station and computer, especially for Customer A where this distance is approximately 50 meters. The operators have to walk this route each time they have to process data in the computer or collect information at the station, which occurs at least two times for each delivery. This distance is almost the same at Customer E in Torsvik. However, Customer E uses portable trolleys with computers and printers at each sorting area. According to the operators and team leaders at Customer E, this is very efficient since it decreases overall walking distance, congestion and queues at the main station. Therefore, SLOG is recommended to use portable computer solutions at Landvetter as well, starting with Customer A.

More thorough planning of unloading - Since the time for the unloading activity of loose cartons is highly correlated with the amount of variants and cartons, as well as the type of loading on the vehicle, it is very important that the preparation and planning of the unloading procedure is performed with consideration. If a carton is misplaced while sorting during unloading, a lot of effort must be spent on locating this at a later stage in the process. This can have a significant impact on the total time and can easily be avoided if the sorting is performed in an accurate manner from the start. Thus, it is more important to emphasize accuracy rather than speed during unloading, which implies correct planning. This is aided by a thorough preparation before the unloading begins.

Better communication when unloading by Long John - When unloading loose cartons with a Long John the operators should know in advance approximately how many pallets the delivery requires, how the different variants should be distributed and who is responsible for each variant. In several of the observed situations, the operators were not aware of this type of detailed information. The situation became clear first when the unloading procedure started and the operators began to read the labels of several cartons. Usually, they apply a trial and error approach, where it in some cases turned out that the delivery consisted of too many different variants to be able to sort during unloading. This meant that sorting had to be performed at the sorting area instead, which resulted in significant total time increases. In general, the estimation is that it is about 60 percent more time-consuming to perform additional sorting at the sorting area than sort the cartons directly during unloading. Therefore, it is crucial that as much as possible of the sorting is performed during the unloading process. Furthermore, the team leader or responsible operator must make sure that the details about the unloading is communicated to all operators involved to minimize misunderstandings.

Decrease the number of volume measurements - Some customers (e.g. Customer A) have to perform volume measurements for certain articles and enter this information separately in the system during the reception process. This is an activity that is rather time-consuming, especially for customers where it occurs frequently. The activity is considered to be relatively unnecessary since the information could probably be obtained more easily from suppliers or from similar products available in the system. Thus, SLL should evaluate other ways to obtain this information and assess if this activity is necessary to perform by operators at all.

Minimize the amount of mixed cartons - Another main time driver in the reception process is the processing of mixed cartons. The time for handling these cartons composes a significant portion of the total time spent on sorting. Splitting and sorting one carton takes approximately five minutes and if there are several mixed cartons in one delivery the task can take hours. Mixed cartons also require additional packing material and processing of several new cartons, which increases the costs for material. Thus, striving to reduce the numbers of mixed cartons to a minimum should be a priority for SLOG. This can for instance be done by encouraging the suppliers to pack unique articles in separate cartons. To avoid unutilized carton space the suppliers can send small quantities in smaller cartons. Furthermore, the customers should be informed about the impact mixed cartons have on the total costs and the benefits of ordering articles in batches of appropriate sizes.

Evaluate the possibilities to implement double cycles - In the case of Customer A, the put away activity is performed by one or two operators on reach trucks that drive between the sorting area and the storage location. When the observations were made, the operators where only transporting articles one way, i.e. they collected a pallet, drove to the item location, left it and went back with an empty forklift to collect a new pallet. A suggestion is that SLOG would benefit from evaluating the impact of combining the put away of full pallets with parts of the outbound process. This could be done by transporting full pallets ordered for picking to the packing station. By applying a so-called double cycle, they can reduce the numbers of empty runs and an estimation is that it will reduce 40 percent of the horizontal transportation time for full pallets.

Direct replenishment to pick location during put away - SLOG is recommended to try to combine the put away process and the replenishment of articles from buffer to pick locations in a more efficient manner. The computer system should be able to calculate if an article nearby the put away location needs to be replenished and signal to the operator to perform this. For instance, this can concern items in the same aisle or at the same shelf level in order to reduce unnecessary transport and waiting. Today, replenishment orders at Customer A and Customer B often end up on queue, which means that operators on a picking route have to wait until the orders are process before they can finish their own activities. Orders for replenishments should be prioritized and processed as soon as possible.

One way to do this is by combining each put away with a replenishment order whenever they are available.

Increase the information visibility for operators - In some cases for Customer A, items are placed on their buffer locations instead of pick locations, even if there is available room for them there. SLL should therefore upgrade the software to also provide information about how many articles are available at the pick location so that the operator can chose to replenish the article even if there is no instant need for it. This could for instance be beneficial to apply in the zone for flow racks, where the buffer locations are located above the pick location and no additional horizontal transportation is needed.

Collect empty boxes during put away - When cartons are placed directly at the pick locations, it is important that the operators open up boxes and remove empty material from the shelves. For several customers, this activity is performed during the picking process, which is often more complicated and time-consuming than if it should have been performed during put away. This is one of the main issues at Customer B, where the aisles are narrow and the shelf heights are low. Today, the operators spend a significant portion of time on opening up boxes and removing covers, as well as collecting empty boxes. This increases the total time since the operators must pause their picking routes to dispose empty boxes. Since the picking process is already the most labor-intensive warehouse process and associated with the largest portion of the total warehouse operating costs (Koster et al., 2006), SLOG should strive to reduce non-value adding elements from this process. Thus, opening up boxes and return empty material should be done during the empty runs back to the station during put away instead.

Always keep the software updated with accurate information - Occasionally during the put away procedure at Customer C, the items do not fit in the storage location since it is fully utilized. Hence, time must be spent on creating new storage locations in the system and then physically transport the items there. This occur more frequently during high season since more articles occupies the shelves in this period. In order to avoid this issue SLL should upgrade the system with correct configurations and volumes. Thus, the system should only allocate a slot when the item physically fits in the shelf.

Increase the efficiency of the replenishment process for Customer B - The current replenishment system is somewhat complicated for Customer B since the team leaders must collect and print the replenishment orders manually. When this is performed, the articles are collected and transported from the narrow aisle buffer to the pick location on the mezzanine floor. This means that the picking operators must wait a long time before the requested articles becomes available for picking. This is something that SLL should strive to improve, for instance by making the communication between production support and operators at the inbound division more efficient and use hand scanners for this activity as well. Another solution is that the system generates replenishment orders before the stock level reaches zero. Hence, the re-order point can be adjusted to one or two items. This will substantially reduce the temporary stock outs and waiting times for picking operators.

Remove pick locations from ground levels in narrow aisles - When interviewing the operators at Customer D, it became clear that the most time-consuming activity during the picking process is picking from ground locations, which was also confirmed during observations. Picking from floor locations means that they have to change forklift, collect the pallet and transport it to a safe zone in order to pick the item. Therefore, it is not preferable to have pick locations on ground level in narrow aisles. This space is better utilized for buffer locations of items with low frequent picks or items on the way to be phased out.

Provide a fix spot for hand scanners on trolleys - During observations of picking from flow racks with trolleys and hand scanners at Customer A, many individual methods were noted between different operators. However, one common factor were the lack of space on the trolley to put the scanner away if needed. Some operators had problem of handling the scanner and picking items at the same time, e.g. if there were many or large items to pick. Several operators also stated that the hand scanners could be heavy and cumbersome to carry during long routes.

Adapt the trolley to better suit the areas of use - Currently, all trolleys are not optimal for picking from higher levels in the shelves at both Customer A and Customer B. During the observations it turned out that some operators had difficulties collecting articles on the upper levels and that they sometimes had to climb on the shelves in order to reach. This is both a time-consuming and unsafe activity, which can be improved by an additional ladder attached to the trolley or other aids that can help the operators to reach the articles.

Evaluate the use of ring scanners during picking - During the observations, several different picking techniques were observed among operators. It was noted that the most efficient operators held their hand scanners in the hand during the whole activity while others went back and left theirs on the trolley or forklift, which resulted in higher average times. SLOG is therefore recommended to evaluate how the use of ring scanners would impact the picking activity, especially when trolleys are used. An assumption is that ring scanners are easier to carry than the hand scanner and that the operator will be able to work more efficient with both hands since the device is attached to the arm or hand.

Minimize the processing time for printers - The processing time for different computers and printers are very long in general, and for Customer B in particular. Currently, it is not unusual that the operators at Customer B have to wait about 23-28 seconds before all documents and labels are printed. Some operators chose to perform other activities during this event, but in general the computer's processing time is the main bottleneck in this process. SLL should investigate why the processing of document takes so long and try to reduce it so that the activity is driven by the operator's working rate instead.

Avoid repacking of boxes in the packing process - One of the main time drivers in the standard packing process at Customer A is the repacking of boxes overfull with articles. This is often the case when the system has provided invalid information concerning the size of the product carriers. Today, it is the picking operator's responsibility to make sure that the boxes are possible to seal when they are placed at the packing area, which can require additional time and innovative packing solutions when the size of the carton is wrong. Thus, the software must always be updated with accurate values and volumes to minimize deviations in the packing process.

7 Conclusion

The conclusion section starts with a short description of how the aim was fulfilled and the main findings of the study. Finally, some fields of future studies will be presented.

7.1 Concluding remarks

The aim of this Master's thesis was to create a calculation tool that considers different time drivers in warehouse operations and facilitates estimations of required manual labor at Schenker Logistics. In order to fulfill this purpose six research questions were formulated.

The goal was to gain a deep understanding of how the standard warehouse processes at SLOG were designed. This was accomplished by observing different customers and creating process maps that displayed the different processes and their corresponding activities. The next step was to identify the most significant time drivers and evaluate how different factors affected the productivity. This was done by reviewing the process maps and thoroughly analyzing the activities with employees at SLOG.

In order to create the calculation tool it was necessary to collect data for the different standard activities by performing time studies. Templates for time studies were created in Excel and smartphones, stopwatches and a video camera were used for the time recordings. The collected data was compiled and analyzed in Excel and later discussed and validated by operators before it was used as basis for the different sections.

The calculation tool was created in Excel and it consists of six sheets; Summary, Process design, Data, Process description, Definitions and Manning. The process design sheet retrieve standard times from the data sheet and calculates the total required time for each activity and process, which is summarized in the summary sheet. The manning sheet calculates the weekly and yearly need of full time employees with regard to seasonal variations. The calculation tool also encloses some guidelines and process descriptions that will facilitate the use of the model and increase its accuracy. After entering all customer specific data, the user can select customer specific characteristics with regard to size and complexity of operation in the summary sheet. This is performed in order to consider the most appropriate PF&D time allowances for the solution design.

The model was tested with different types of quantitative data from the observed customers, and the results were satisfying. The calculated differences between the generated required times and the actual times turned out to be higher than first anticipated. However, a relationship between customers related to their size and complexity was discovered. This acted as the foundation when determining the estimated PF&D time allowances currently used in the calculation tool.

The aim of the development of the calculation tool was to facilitate and make the design and quoting process for SLOG more accurate. The tool is not only considered to have a more reliable time database, but is also more accurate concerning the level of detail compared to the old system. The calculation tool can also have other areas of use besides quoting new customers. It can for instance be applied to evaluate productivity for current customers and allow comparisons between different designs.

7.2 Future studies

This section will discuss areas and activities in inbound and outbound processes that would benefit the precision of the calculation tool if they were further analyzed and discussed. The following topics might be of interest for SLOG to evaluate in the future in order to gain deeper understanding of important time drivers and obtain more valid data when calculating required manual labor to perform these activities.

One significant element outside the scope of this thesis is related to customer specific services, i.e. VAS. Typical VAS activities are the processing of claims and returns or other special requests from the customers. It would be of interest to identify and analyze different VAS activities in order to find time drivers. Thus, SLOG is recommended to perform studies in this field in order to increase the overall understanding of how different customer requirements impact the manual labor of their warehouse operations.

Furthermore, replenishment orders are not covered in this thesis. Replenishment of articles can be a rather time-consuming activity, which also increases the total time for other processes (e.g. picking) if it is not performed in an efficient way. Hence, this activity is worth analyzing in the future in order to identify time drivers and possible ways to reduce the replenishment lead-times.

Activities concerning material feeding and replenishment were also excluded from this study, since these activities show great variety between different customers. Thus, a recommendation for further work would be to evaluate the time spent on supplying the stations with material.

Further studies should also concern the impact of different types of picking techniques on time spent on picking and soft values for different processes. It would be of interest to compare pick-by-voice, pick-by-light and ring scanners with the methods currently used at SLL. The assumption is that there are great potentials for time-savings mainly in the picking process. This in turn can reduce the total required need for blue-collar manning and free up internal resources.

It is assumed that the packing process only considers packing of rather standardized articles. However, in reality there are many situations where items require special wrapping or processing. The additional time spent on this activity is not considered in the calculation tool. Thus, a suggestion for future studies is to analyze how bulkiness affects the packing process in order to calculate an add-on time that is dependent on the volume, length or weight of these items.

There are some activities in the inbound processes that depend on multiple arrays of factors in reality, but only consider one parameter in the calculation tool. A recommendation for future studies is to analyze these activities further to obtain more accurate values and gain deeper understanding about the different time drivers. This can be achieved by for instance creating an equation or matrix that considers more than one factor. There are three activities in the calculation tool that are especially relevant for these studies. The first one is sorting of unsorted goods, which is currently based on the assumption that the number of cartons is the main time driver. SLOG is recommended to also evaluate how the number of SKUs, pallets, weight and volume of items etc. impact the time for this activity. The second activity is sorting of mixed cartons. Currently, only the amount of cartons is considered in the calculation tool, however in reality the activity is also driven by the number of SKUs and items each carton contains, as well as the number of new cartons. The final activity is verification of incoming goods. The section in the model depends solely on the number of cartons, but in reality it is also driven by the number of SKUs, number of pallets and how the information on each carton is obtained.

The time allowances calculated in this study are based on validations for four different customers; two large customers with complex processes, one small customer with complex processes and one small customer without complex processes. Hence, the combination of a large customer with less degree of complexity is missing. A recommendation for future studies is to determine the PF&D time allowances for this type of customer as well. It is also possible to test the calculation tool with additional customer data in order to validate the obtained PF&D time allowances.

A final recommendation for future work would be to investigate how the use of double cycles for the put away process impact the total time in reality. According to the tutor at SLOG, several other cases have shown that the productivity rates have increased significantly after implementation of double cycles. A theoretical estimation of 40 percent time reduction of the transportation time in the put away section is used in the calculation tool. Thus, it would be of interest to evaluate the practical impact of double cycles in the special case of SLL.

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Appendices A – Example of time study templates

Put away

Average times:		29,780					7,425	18,083	4,271	**29,2**			
Customer	**Operator**	**Pick techniq**	**Vehicle**	**Zone**	**Type of item**	**Level**	**Positioning**	**Put away**	**Positioning back**	**Total time**	**Date**	**Observer**	**Comments**
Customer X	Operator A	Scanner	Reach truck	Wide aisle	Pallet	40	17,1	15,4	4,7	37,2	09-apr	S	Operator che
Customer X	Operator A	Scanner	Reach truck	Wide aisle	Pallet	40	5,5	19,7		25,2	09-apr	S	Operator che
Customer X	Operator A	Scanner	Reach truck	Wide aisle	Pallet	20	11,3	18,8	5,3	35,4	09-apr	S	Operator che
Customer X	Operator A	Scanner	Reach truck	Wide aisle	Pallet	20	4,1	20,4	1,4	25,9	09-apr	S	Operator che
Customer X	Operator A	Scanner	Reach truck	Wide aisle	Pallet	50	3,2	21,3	2,5	27	09-apr	S	Operator che
Customer X	Operator B	Scanner	Reach truck	Wide aisle	Pallet	30	6	12,9	3,8	22,7	20-mar	S	Operator che
Customer X	Operator B	Scanner	Reach truck	Wide aisle	Pallet	30	7	17	7	31	20-mar	S	Operator che
Customer X	Operator B	Scanner	Reach truck	Wide aisle	Pallet	60	5,2	18,5	5,2	28,9	20-mar	S	Operator che

Name of study: Inbound - put way
Customer:
Date:
Order information:
Other:

Elements:

nr		**1**	**2**	**3**	**4**	**5**	**Description:**	**Start:**	**End:**	**Notes:**
1	Prepare forklift						Prepartion if necessary, fetch forklift etc.			
2	Horizontal transport to location*						Collect pallet, check position for first item, drive there	Collect pallet	Stop at location	
3	Vertical positioning to location*						Check position level, move up to that level	Check position	Stop at level	
4	Put item away						Place item in shelf, enter check number/cross from list	Start horizontal movement	Check list	
5	Vertical movement down*						Return to ground position, check new location	Start vertical movement	Back at the ground	
6	Transport empty forklift back*						When all items are processed, transport empty forklift back	Start movement	Forklift stops	

* These data is only used for validation of model