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Improvements of Warehouse Operations to Reduce the Impact of Quality Deficiencies

Master's Thesis in the Master's Programme
Supply and Operations Management

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Abstract

In the increasingly competitive market of 3PL:s, it is important to have efficient processes limiting non value adding time as much as possible while at the same time delivering high quality services. There are a number of different quality deficiencies that may occur in the warehouse operations and DB Schenker Logistics AB wants to understand their current situation and how the impact of quality deficiencies can be reduced to make their operations more efficient. The purpose of this thesis is therefore to increase the understanding of quality deficiencies occurring in the warehouse operations and how the operations can be improved to reduce the impact of the deficiencies. Three of Schenker's larger customers were the focus for the thesis. To be able to fulfil the purpose, five different data collection methods were used which were interviews, observations, time studies, surveys and data from Schenker's databases. The results from the data collection were the identification and quantification of the time consumption for managing a number of different quality deficiencies. Based on the quantification, suggestions for how to reduce the impact of the deficiencies with the largest impact were presented. The main areas which Schenker can work with and study further are picking errors and their consequences, transportation and the education of new employees.

Keywords: Cost of poor quality (CoPQ), quality deficiencies, warehouse operations

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Tobias Karlsson *Nils Thylén*

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List of Abbreviations and Definitions

3PL: Third party logistic

Appraisal: Time spent on appraising the quality of operations, for example inspections. Part of CoPQ concept.

CT: Control tower

CoPQ: Cost of poor quality

End customer: The customer that Schenker delivers the goods to

GL: Group leader

Internal error: All errors that needs to be handled with extra activities for example picking errors. Part of CoPQ concept

Mezzanine: Second floor in a warehouse

Non value added: Activities that do not add any value to the operations which may be a result of another deficiency. Part of CoPQ concept.

Prevention: Activities that are performed to reduce the occurrence of internal errors in the operations.

PS: Production support

Quality deficiency: Deviations from routines that require time to correct and activities that are in place to ensure high quality.

SKU: Stock keeping unit

Supplier: The supplier of the goods that is sent to the warehouse

VAS: Value added services

WMS: Warehouse management system

1. Introduction

A background to the third-party logistics market and what kind of changes that it currently faces is presented in this chapter and how DB Schenker Logistics AB, hereafter named Schenker, is affected by these changes. The background is then concluded with the purpose of the thesis which is to analyse quality deficiencies that are occurring in Schenker's warehouse operations. Warehouse operations consists of a number of different processes such as receiving goods, storage, order picking and shipping (Gu, Goetschalckx, & McGinnis, 2007).

1.1 Background

The third-party logistical (3PL) market concerning warehousing in Sweden has developed during the last 18 years, from having a total turnover of 4 billion SEK at the beginning of the 21st century, to that the 10 biggest actors are having a turnover of 7 billion SEK in 2018 (Hultén, 2018). A 3PL is an actor that supplies many services which may include transportation, warehousing and order management, as well as other value adding services (Rosén, 1999). There are also changes in the market which concerns newcomers and specialised companies. There are actors that are focusing on delivering a low price service and others that are working towards a niche market such as focusing on e-commerce (Hultén, 2018). It is becoming more common for 3PL:s to specialise in a specific type of customers instead of offering all services to all customers. 3PL:s that are more customer selective and only accept customers which have similar demand in frequency, size and value of the goods could potentially benefit from investing in specialized equipment in the warehouse operations (Specter, 2017).

The price of 3PL services regarding warehouse operations are dependent on the capacity utilization, meaning that when actors have a lot of vacant space, they have a worse negotiation position which leads to lower prices (Hultén, 2018). The availability over time comes in cycles as contracts in this type of business are commonly three to five years.

Schenker is the third largest 3PL company in the Swedish market and is looking for ways to increase their competitiveness to attract new as well as to keep their current customers. Schenker is facing some of the problems for 3PL mentioned above such as specialised actors, price competition and that the contracts are quite short term. The short term contracts make it difficult to make large investments since the investments have to be depreciated during the contract period to reduce the risk.

In this competitive environment it is important to keep track of the cost of operations to continuously develop the processes and to make the operations more efficient (Slack, Chambers, & Johnston, 2010). This means that if Schenker can keep track of and spend little time on managing quality deficiencies it may be possible to keep or gain new customers. Quality deficiencies are defined for this thesis as the following: deviations from routines that require time to correct and activities that are in place to ensure high quality. The definition of quality deficiencies used in this thesis is similar to the concept cost of poor quality (CoPQ). According to Sörqvist (1997), CoPQ is the cost that occurs because a process is not working perfectly. Even though CoPQ is usually measured in monetary terms, Schenker wants to understand the time consumption arising from different quality deficiencies and how it can be reduced. The company has dedicated staff to manage quality deficiencies but does not exactly know which deficiencies are occurring or how the time is distributed among them.

1.2 Purpose

The purpose of the thesis is to increase the understanding of quality deficiencies occurring in the warehouse operations and how the operations can be improved to reduce the time-consumption of managing deficiencies.

The purpose of the thesis will be fulfilled by answering the following research questions:

RQ1: *What quality deficiencies occur at Schenker's warehouse operations and how can they be classified?*

RQ2: *How much time is spent on managing quality deficiencies?*

RQ3: *How can the time spent on quality deficiencies be reduced?*

1.3 Delimitations

Schenker requested which customer to be analysed and these were three larger customers as the impact of improving quality deficiencies for those customers may lead to larger time-savings.

The scope of the thesis is to analyse quality deficiencies in the internal warehouse operations. The external consequences of quality deficiencies such as the need for extra shipments from the warehouse, cost of replacement of goods and time consumed by the customer's staff, are not included.

If there are activities that are performed as a value added service, these are not included in the scope of this report. Value added service (VAS), are activities the customer wants Schenker to do which are not part of the contract between Schenker and the customer. Schenker performs the required activity and bills the customer at an hourly rate. Certain activities which are considered to be related to the concept of cost of poor quality but has to be performed by Schenker in accordance with the contract with the customer are excluded from the thesis. These activities will further be explained in chapter 5.

The report does not include how implementation of potential improvement suggestions should be conducted.

1.4 Thesis Outline

The thesis has been divided into nine different chapters and a short description of these chapters are presented in this section.

Method

The first chapter after the introduction is the method where the research approach for the thesis is presented. This is followed by a presentation of which data collection methods that have been used. The research process of the thesis is then explained, and the last section of the chapter presents research quality.

Theoretical Framework

In the theoretical framework chapter, relevant concepts for the thesis are presented. The main concept is cost of poor quality which was used to provide a structure for the quantification. What cost of poor quality is, how it can be classified as well as how cost of poor quality can be measured is explained. Other concepts that were also relevant for the thesis were the seven wastes of lean production, warehouse operations, order picking and sustainability. How the theoretical framework is related to the data collection and the three research questions is presented at the end of the chapter.

Customer Cases

The empirical findings of this thesis are separated into three chapters. The chapters Customer Cases and Identified Quality Deficiencies are related to research question 1 and in the chapter Time Consumption of Managing Quality Deficiencies the results for research question 2 are presented.

In the Customer Cases chapter, a general description of the warehouse operations is provided including the activities performed at each process step. This is followed by a description of the support functions that support the warehouse operations if any problems occur. Specific processes for each customer are presented and explained in the last section of the customer case chapter.

Identified Quality Deficiencies

The quality deficiencies that have been identified for the customers are presented and classified according to a cost of poor quality model described in the theoretical framework. First, the quality deficiencies that are common for the three customer cases are presented followed by the deficiencies which are specific for each customer.

Time-consumption of Managing Quality Deficiencies

In this chapter, the results from the quantitative data collection is presented. This is performed on customer specific level and are presented by first showing what functions are spending time on quality deficiencies. This is then broken down in different categories related to the cost of poor quality concept. Each customer section is then finalised by presenting which quality deficiencies that are studied further in the chapter Analysis of Differences and Potential Improvements.

Analysis of Differences and Potential Improvements

In this chapter the collected data are analysed and compared between the customer cases. The most relevant quality deficiencies regarding time-consumption are analysed, and improvement suggestions are presented.

Discussion

Discussion about the fulfilment of the purpose and research questions, generalizability of the findings, the impact of the limitations and sustainability, are presented in this chapter. Areas which could be studied further is also presented as well.

Conclusion

In the final chapter of the report the main findings are presented and recommendations for what Schenker should do.

2. Method

In this chapter the method used for the thesis is presented. Different possible research strategies are presented and the choice of strategy for the thesis is explained. Different research methods that were used to collect data for the project are presented. A figure and explanation of the research process used in this thesis are presented also and research quality is discussed at the end of the chapter.

2.1 Research Approach

There are two main areas about how data can be collected when it comes to a research project and these are quantitative and qualitative. One way of comparing the two is to interpret quantitative methods as the realist way, meaning that the truth is in numbers (Muijs, 2010). This should be compared to qualitative data collection, which is said to be subjective in the nature of methods, as it means that the researcher puts a subjective view on how a phenomenon is analysed (Muijs, 2010). According to Berg (2001) the two strategies of research will give two slightly different views of the subject being analysed.

When working with quantitative method, the research strategy is often to find literature about theory that can be applied to a situation, develop a hypothesis and then test the hypothesis (Barczak, 2015). This method of working is called deductive approach and is often a structured way of working. There is a risk by using this method that the researcher focuses more on making the empirical findings conform towards the theory and thereby be biased (Barczak, 2015).

When using qualitatively methods the way of working is often inductive, which is that the researcher observes and searches for patterns, then writes the hypothesis and develops it into theory (Barczak, 2015). The conclusions from these types of research cannot be completely certain, since new observations may lead to the conclusion being incorrect (Fejes & Thornberg, 2016).

There is a third method called abductive and this is when the researcher creates a hypothesis that can explain a singular empirical case better than other hypothesis that are directly linked to a theory according to Fejes & Thornberg (2016). This hypothesis then works as a provisional explanation which can further be tested.

From the abductive perspective, Dubois & Gadde (2002) developed a method on how to work with case studies. They mean that when working with a single case it is possible to gain insights about the area that are hard to get from just using theory. By going between the different phases of the research project such as empirical findings and the theory, it is possible to develop a deeper knowledge about the interrelations between the two. It is also when the researcher confronts the theory against the empirical findings that new insights of what is missing in the theoretical framework can be gained (Dubois & Gadde, 2002). The method presented is called Systematic combination, which contains two main aspects, first the matching between theory and reality, and secondly the direction of where the project is going. These two aspects affect the analytical framework being used, the case itself, what theory is needed and what needs to be collected from the empirical world (Dubois & Gadde, 2002). An illustration of this method is shown in Figure 1.

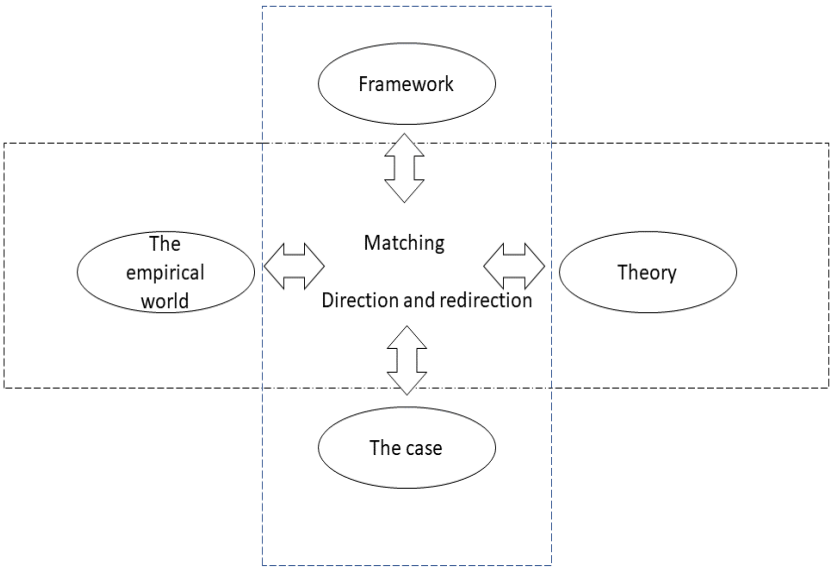

Figure 1: Systematic combining based on Dubois & Gadde (2002)

This thesis used an abductive approach since there was not a clear hypothesis of literature about what should be tested or analysed. Since the case is constantly operational and therefore prone to change, new insights led to the need of gathering new theory and thereafter use it to explain and develop a way on how to use these new insights. In this thesis both qualitative and quantitative methods were used.

2.2 Research Methods

Research methods are techniques that are used to collect data in scientific investigations (Bryman, 2011). A combination of several different techniques was used to collect both quantitative and qualitative data. Each data collection method has advantages and disadvantages and by combining different methods, it may strengthen the advantages and reduce the disadvantages that would occur if only one particular method would be used (Bryman, 2011). Which methods that were used are presented in this section.

2.2.1 Interviews

Interviews may vary on how structured the interview is, from highly structured to unstructured (Wienclaw, 2017). A highly structured interview has questions that are worded in an intentional and specific way and then asked in a certain order during the interview. The interviewer may not deviate from the prescribed order of the questions and the questions are asked at every interview. In a highly unstructured interview, there is only loose format which the interviewer follows, and the interviewer may ask any follow up questions (Wienclaw, 2017). There is also a third type of interview, the semi-structured interview which is somewhere in between the two other types (Bryman, 2011).

There are benefits and drawbacks with the different interview types. Having a very unstructured interview with many open questions where the interviewee can answer freely can result in finding unexpected answers, but it may be time-consuming for the researcher to process and code the answers since the answers might be quite varied (Bryman, 2011). The opposite is true for a highly structured interviews, novel answers might be lost but it is easier to process. More open questions may be used in new areas or early in the research when the interviewer needs to

develop a deeper understanding for the studied system (Bryman, 2011). The answers from early interviews may then be used to create a more structured interview form later in the project.

Interviews were held with people at different levels of the company to gather information on what they believe are quality deficiencies in the processes and what they are aware of today. Interviews were held with supervisors, with employees at production support, group leaders, control tower and superuser for the customers (Appendix I). At the start of the project mostly semi-structured interviews were held where questions in a few major areas of interest were prepared in advance (Interview guide 1, Appendix II). In the beginning of the project the knowledge about the warehouse operations was quite low and it would have been difficult to have a highly structured interview since much was unknown at this point. Having a highly unstructured interview might not have been the best alternative either since interviews were held with people at different levels of the company and to be able to compare the answers a general structure for the questions was needed. The interviews formed the basis of what kind of quality deficiencies exist today.

A more structured interview type was used at a later stage in the project to confirm that collected data seemed to represent an average work day for certain employees. This will be explained further in subsection 2.3.5. In total 23 interviews were held, distributed among the customers in the following way: 9 for customer A, 7 for customer B and 7 for customer C. In addition, questions were asked through email or in person throughout the project to follow up on findings.

2.2.2 Observations

Observation is another research method that may be used to get an understanding of social interactions and behaviour (Bryman, 2011). A benefit with observation compared with interviews or surveys is that the researcher can directly see a behaviour that the respondent in an interview might have forgotten to mention or are not aware of that they are doing. However, there is also a problem with the effects the observer has on the person being observed. If the observed are aware that a researcher is observing them, it might affect how they behave. This effect decreases the longer a person is being observed because the person gets used to it and if it the observed person works in an environment that demands high attention (Bryman, 2011). The reliability of observations can be increased if more than one observer is there to make the observation.

In the data collection for the thesis, observations were used in the beginning of the project to learn more about the flow of the goods and the different activities involved in the processes. Observing the operations could also help identify quality deficiencies not mentioned in the interviews. Relevant employees were then asked to answer questions about the observed quality deficiencies

2.2.3 Secondary Data

The report has used existing data from Schenker's database that is connected to the existing quality issues to get an understanding of the current situation. A big issue that comes from using secondary data sources, is that the data is not collected for the purpose of the study (Emerald Publishing, 2018). This means that the data needs to be analysed and an understanding of what it stands for needs to be gained to be able to make use of it. If some part of the data was difficult to make sense of, the employee responsible for managing the data was consulted to sort out any questions to determine if it was possible to use the data in its existing form.

2.2.4 Time study

Time study is a technique which can be used to measure the time required for an operator to complete a task (Zandin, 2001). The operator that is being studied should be qualified, that is has done the task several times and should work at a normal pace. The researcher may also look for ways to improve the method while observing the operator and conducting the time study (Zandin, 2001).

Choosing an appropriate operator to do the time study on is important. An experienced operator that has no issues with being studied may be a good choice while an operator for being very reluctant, can decrease the accuracy of the time study (Zandin, 2001). As was the case for observation, the fact that the operator is being studied may affect their performance.

Time studies were used in this thesis to understand the speed of movement of operators, both for walking and driving forklifts. They were also used to collect data about the time that an appraisal activity took to perform. This was performed by taking the time for a warehouse operator to count the number of items of every order. The data collected was later used to estimate the total time that was spent on this activity.

2.2.5 Survey

Survey is another method that researcher can use to collect data. It consists of a questionnaire which the sample population are to answer on their own and are then supposed to give the completed survey to the researcher (Bryman, 2011). A survey is in many ways quite similar to a highly structured interview where the questions and the order are set. Surveys usually have more closed questions than in an interview.

Bryman (2011) explains several ways to increase the response rate of a survey. To explain the reason for the survey, have clear instructions and the layout of the survey which is easy to understand are some ways to increase responses. Having at least two reminders to do the survey has also been shown to increases response rate (Bowling, 2005).

The survey method was used to collect quantitative data about the frequency and time of different quality deficiencies occurring in the warehouse operations. The survey was filled out each day for a period of ten working days. During this period the employees were contacted a number of times to make sure that there were no misunderstandings about what should be filled out and also to show the importance of the study. The time that they had estimated per day was then compared to the number of hours that they had been working that day. If there were time missing, further questions were asked to make sure that as much as possible was included into the survey and the survey was revised to include more activities. Which employees that were included in the survey are presented and explained in chapter 6 since knowledge about the flow and the different functions is needed to understand the reasoning. A general configuration of the survey can be seen in Appendix III.

2.2.6 Literature search

When searching for relevant literature to create a deeper understanding of the subject and develop the theoretical framework for the thesis, papers in academic journals were used together with some books. A majority of the papers that were used had been peer-reviewed before being published in a journal. According to Rowley & Sbaffi (2018) peer-reviewing is a process in which an article is reviewed by other experts in the same field before the article is accepted for publication in the journal. Papers that have been peer-reviewed increases the likelihood of the

papers having high standard. The main search portal used for the project was lib.chalmers.se and Google Scholar. Examples of search words were: *cost of poor quality*, *lean production, measuring cost of poor quality, 3PL, warehouse operations* and *order picking*.

2.3 Research Process

In Figure 2, the process for the thesis is shown and each step is explained in the subsections below. The steps in the dashed rectangle will be explained in the customer analysis subsection. The steps in the dotted rectangle (the lower one) is explained in the finalisation of data subsection.

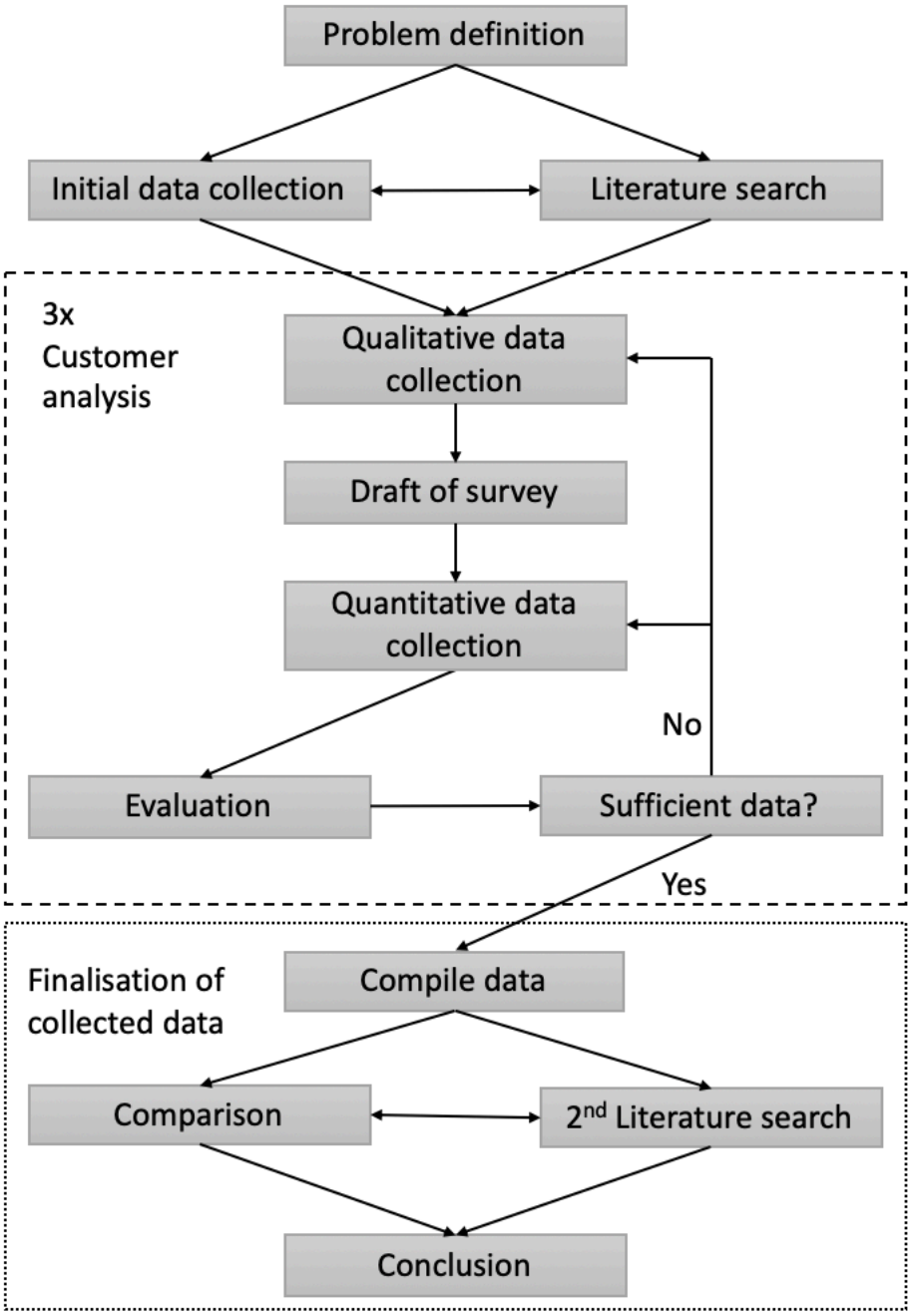

Figure 2: Intended process for the thesis

2.3.1 Problem Definition

The first step of the project was to define the problem and the purpose of the thesis. It is a crucial step to determine what the actual problem is, if the problem is not defined correctly it might lead to a solution at the end of the project that is not for the actual challenge. Kauda (2012) means that the problem definition should be stated in such a way that it cannot be misinterpreted. In the beginning of the project the problem definition was discussed with the project tutor at Schenker and was revised until an agreement on the formulation and the content of the statement. Which processes and activities that were excluded from the thesis were also decided in this first step.

2.3.2 Initial Data Collection and Literature Search

When a problem definition was agreed upon, research on different ways on how to approach the problem was conducted. Literature search and reading were performed to learn about the subject and find methods or frameworks that could potentially be applied to the case. At the same time the initial data collection was started. Explorative interviews of a semi-structured type were held to learn more about the processes and responsibilities of different employees. Furthermore, observations of the warehouse operations were conducted to learn more about the flow of goods in the warehouse. By observing the operations, a deeper understanding of the overall flow from the inbound process through all operations until outbound was achieved. The focus of the initial data collection was to understand the flow in the warehouse at Schenker and also to determine which employees would be important to interview about quality deficiencies. The information gained from the interviews and observations also guided further literature search.

2.3.3 Customer Analysis

After the initial data collection, the next step was to collect data about the different customer cases. The literature search conducted in the first step of the research process resulted in a framework to follow when working with quality deficiencies. Customer analysis consisted of five steps and these five steps were conducted for all the three customer cases. Qualitative data collection which resulted in a draft of a survey, quantitative data collection through the survey and time studies, evaluation of collected data and finally a decision whether the collected data was sufficient for the thesis.

Qualitative Data Collection

In the qualitative data collection part, interviews with employees that are involved in managing problems in the warehouse operations and group leaders for different parts of the warehouse operations were held. These employees had been identified in the initial data collection and were considered important for answering the first research question of the thesis. In the interviews, quality deficiencies were explored, mainly which quality deficiencies that may occur in the warehouse operations and their frequency, how a particular deficiency is managed, and the severity of the deficiency. The different parts of the flow were also observed on a number of occasions. The observations were conducted to identify deficiencies discussed in the interviews and see how they were managed. Furthermore, through the observations deficiencies that were not mentioned in the interviews could also be identified.

Draft of Survey and Quantitative Data Collection

The qualitative data collected from the interviews and the observation were compiled and a draft of a survey was created and tested for a couple of days by the people identified to be most involved in managing deficiencies. If the frequently occurring deficiencies were included in the

survey and there were no questions from the employees filling it out, then the actual data collection began. The survey was, as mentioned in subsection 2.2.5, to be filled out daily for ten working days. The commonly occurring quality deficiencies as mentioned in the interviews were included in the survey. How many times a quality deficiency happens, and an estimation of the total time spent on handling it was to be recorded in the survey at a daily basis. If any unexpected problems happened, then these problems should also be recorded in the survey. When handing out the survey, the different categories of quality deficiencies were explained, and a description of the deficiencies was also handed out.

Evaluation

During the survey period the employees filling out the survey were contacted several times to find out if there were any questions about the survey or if any new problems had occurred. The time logged in the survey was also followed up on a daily basis to be able to understand if the survey captured a workday or if there were many hours missing.

After the ten working days data collection period a final evaluation and confirmation of the data collected from the surveys were performed. Interviews were held with the employees having filled out the survey to confirm that the time spent on managing the deficiencies were distributed according to the collected survey data. The collected data was also confirmed by interviewing the supervisor at each customer case who knows on a general level what the employees spend their time on. The final step of each customer case was to determine whether the data collected was sufficient or if the survey period should be extended. If the compiled data was confirmed by the employee filling out the survey and the supervisor, then the data was considered to be sufficient. Time keeping logs were collected from Schenker's databases and compared to the time gathered from the surveys.

Customer Analysis Loop

The three customers that were the focus for the thesis were geographically far apart so to make the collection of data easier, the data collection for the first customer was completed to a large extent before the collection of data started for the second customer. When data had been collected from the first customer the same data collection methods were applied to the second customer and then later the third. For the second and third customers, knowledge about possible deficiencies had already been develop when collecting data about the first customer. These deficiencies were explored in the interviews at the two remaining customers to learn whether there were similarities in the problems faced at the different locations. The survey was slightly altered for each function since some deficiencies were not handled by all functions.

2.3.4 Finalisation of Collected Data

This final part included compile data, comparison, second literature search and conclusion as can be seen in Figure 2. In this final part, the data collected from all three customers were compiled and the time spent on the quality deficiencies were analysed for each of the customers. The time spent on quality deficiencies were separated into different categories of a model for CoPQ (presented in 3.1.2). Similarities and differences in managing quality deficiencies between the customers were studied, to see whether there were any practices that were better to manage a certain problem. If one customer had a process which generated fewer deficiencies or was better at handling a problem, then it was investigated whether it could be applied for the two other customers. The quality deficiencies which took the most time to handle for each customer were considered to be the most important and the main focus for the third research question, to find potential improvements. A second literature search was conducted at this stage

of the process to see if similar problems have been studied in academic research that could be applied to the thesis.

Lastly in the conclusion, next steps for what Schenker could do in the future were suggested. Recommendations for how to reduce the most important quality deficiencies for each customer were provided.

2.4 Research Quality

How the collected data was validated is presented in this section as well as the reliability of the data. A brief presentation of the ethics of the thesis ends this chapter.

2.4.1 Validity

Validation refers to how well a data collection tool measures what it is intended to measure (Lewis-Beck, Bryman, & Liao, 2004). A measurement tool may not be validated by itself, it may be validated in relation to what it is intended to measure. Different data sources were used to validate the data and triangulate the results. This was mainly used to validate the data collected from the survey to make sure it captured the actual time spent on managing quality deficiencies. It was performed by using secondary data, interview answers and in some cases time studies.

To make sure that the survey was valid and measures the quality deficiencies that occur in the warehouse operations it was tested before the actual data collection began as mentioned in 2.3.3. As has been mentioned, when data had been collected from the surveys, the data were compiled and the employees having done the survey were asked if the data approximately matches what occurs in the operations. This was further confirmed by the customers cases supervisors.

The employees that were dedicated to managing quality deficiencies were asked about what they did more on their workday when the number of hours filled in in the survey did not match an actual workday. This was performed to make sure that the survey included a majority of their work tasks.

2.4.2 Reliability

Reliability shows how consistently a data collection instrument measures a phenomenon (Lewis-Beck et al., 2004). Relative inconsistency and unsystematic variations are measured to determine the reliability of collected data. Unsystematic variations, that is random errors, may create inconsistencies in the data collected from a respondent. A measure may be reliable but that does not necessarily make the measure valid (Lewis-Beck et al., 2004).

There are some issues concerning the reliability of the data collection. Since the collection took place during a short period of time there is a risk of random variations affecting the results. To reduce the risk, interviews were held with the people having filled out the survey and supervisor to confirm the reliability of the data collected and if any major discrepancies occurred during the data collection.

2.4.3 Ethics

There are many different parts that concerns ethics in doing research. This report made sure to handle the anonymity of the people involved in the work, by not using the names of people who either helped with the collection of data or the people that were interviewed. The reason for doing this is to avoid the staff getting in trouble as a consequence of participation in the project, which is the main reasons for anonymity according to Given (2008). The author further states

that researchers should understand what harm the research may have on the participants and thereafter take appropriate actions to prevent or limit the harm to the participants.

Another part of research ethics concerns that the participants should be informed about the research purpose, how the information will be used in the research and that participation should be voluntary (Given, 2008). To achieve this, the participants were given a description about the thesis purpose and if it was possible to record their answers before questions were asked. The same approach was used for the survey data collection where the participants were told what the data would be used for and if they could to help.

3. Theoretical Framework

In this chapter, literature used to explain and understand the subject of the study is presented. Literature regarding cost of poor quality (CoPQ), lean and the seven wastes, methods on how to quantify CoPQ, warehouse operations and sustainability are presented. The chapter is concluded with an explanation on how the theory relates to the data collection and how it will be used to answer the three research questions of the study.

3.1 Cost of Poor Quality

Feigenbaum (1956) makes three broad categories in what is called the PAF model which is a model for CoPQ and PAF stands for prevention, appraisal and failure. By categorizing them into these three groups it is possible to analyse the relationship between different types of quality costs. There is a connection between having high failure cost and to see an increase in the appraisal cost as well, since having failures increases the need to appraise the quality to detect failures (Feigenbaum, 1956).

Feigenbaum (1956) defines the failure cost as the cost that occurs as a consequence of having poor quality of the products which includes scrap, rework and field complaints. The appraisal cost is defined as all costs that arise because of formal quality evaluation, inspections and audits to detect faulty products before the products are sent to the customer. The last group, prevention, is defined as the costs which are caused by making sure that the quality issues do not occur and includes training, maintenance and quality engineering (Feigenbaum, 1956).

3.1.1 Visible and Hidden Quality Costs

In many companies, the accounting system may be hiding some of the cost that can be included in CoPQ, which means there are hidden cost related to the concept (Krishnan, 2006). These are costs that are not measured or are accepted by the company, and then divided out as an overhead cost according to Krishnan (2006). The author further states that hidden costs from administrative quality issues are often higher than those from manufacturing, since they are harder to target.

Even though there may be decisions in companies to work with identifying hidden cost, companies may fail to do so because not all people can be involved in the process. If not everyone is involved, it is hard to realise what the hidden costs are since it is difficult to capture all activities that have to be performed to manage a certain issue (Krishnan, 2006). A common way of showing the aspect of hidden quality costs is to visualise it as an iceberg, where the visible costs are above the water and the hidden or less visible costs are below the surface (Krishnan, 2006; Kent, 2016). A visualisation of the iceberg is shown in Figure 3.

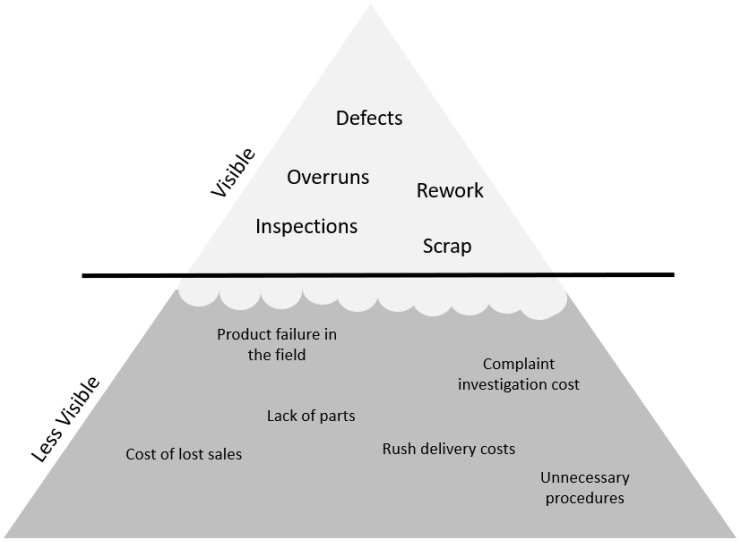

Figure 3: Visualisation of Hidden and Visible cost based on (Krishnan, 2006).

The issue with hidden cost of quality is further confirmed by Sörqvist (1997), who mentions that even if efforts have been made to make it measurable, it has been difficult to bring the hidden costs in to accounting system. The author further states that some costs are difficult to measure such as bad will compared to quality costs that occur in production, which is the most developed area of the CoPQ. Since the quality focus has been more towards the production side of the industry, this may have led to sub-optimisation in the CoPQ work where other parts of the company have been overlooked.

3.1.2 Classification of Cost of Poor Quality

There have been many different models for classifying CoPQ developed from the PAF model, one of them is Harrington (1999). The author's classification is based on the view that not having quality generates costs. This is further backed up by this citation:

> Harrington (1999): *"Quality is not the cost of providing an output. It is the value the customer receives from the output"* (p. 224)

This means that the quality of a product or service concerns the connection between the price that the customer needs to pay for an item or service and their experienced value according to Harrington (1999). The author states that there are not necessarily any benefits from surpassing the expectations of the customer, but a service should not be delivered to a standard below that expectation. There needs to be a system in place that can define what is fit for use, and what is the optimal level of quality to deliver.

Harrington's (1999) view on quality leads into the definition of what the poor-quality cost is, which is defined as the costs that can be allocated to activities that are needed to prevent failures from occurring in the operations. The author further includes all costs that are allocated to inspections and determination of the output as well as costs that arise as a consequence of a service or product not meeting the customers expectation.

To classify the different costs that can be allocated to poor quality, Harrington (1999) divides it into two main groups (see Figure 4). Direct poor-quality costs contains two subgroups, which are costs that are controllable and cost that are the results of poor quality called resultant. Kent

(2016) mentions that the resultant costs can be internal or external where both costs could be connected to rework and failure events. The author points out that the difference between external and internal costs is if the failure event is affecting something at the customer side (external) or affects the company's internal operations (internal). In the controllable subgroup Harrington (1999) divides the group into three categories. Costs for activities to prevent failures from occurring are called prevention costs, for example training. Activities that are performed that do not add value to the system are called non value added. The last cost in the controllable category, appraisal costs, are the costs that arise because of inspecting the quality of products or services.

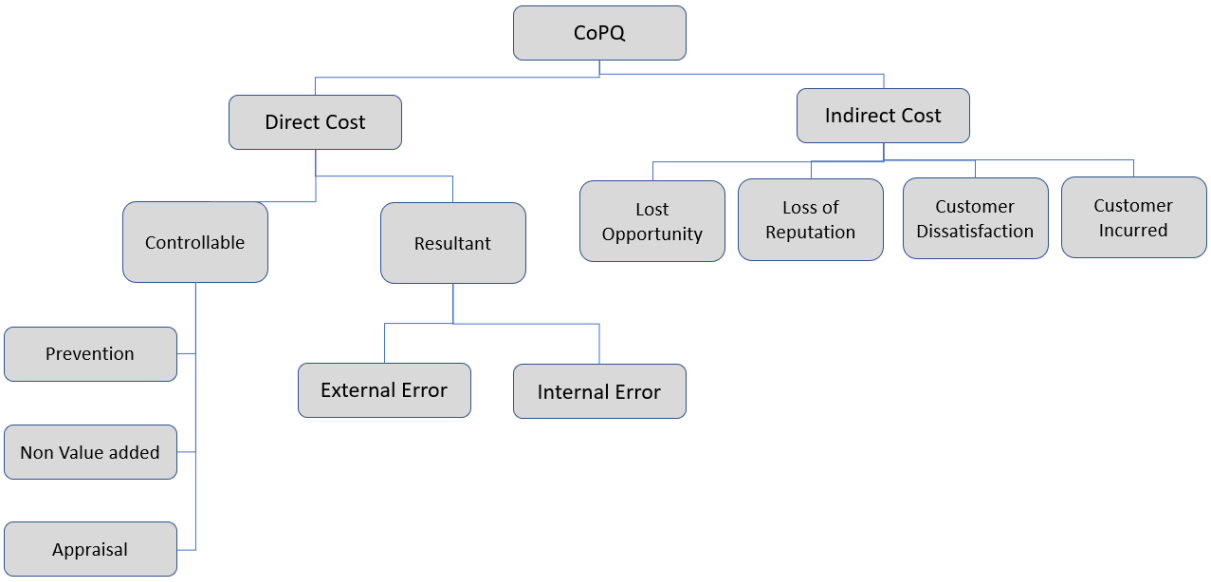

Figure 4: Categorisation according to Harrington (1999).

The second main group is indirect costs which can occur from poor quality and is divided into four subgroups by Harrington (1999). The author defines indirect costs as the cost that cannot directly be traced or measured in the accounting books of a company. The first cost included in this group is cost of lost opportunities, which is the cost of customers choosing a competitor. Another indirect cost category is cost associated to the change of customers attitude to the company and makes it quite difficult to measure. Harrington (1999) calls this cost loss of reputation. Another area that is hard to measure is the one regarding the dissatisfaction of a customer, which is as a binary attitude of the customer, either the customer is satisfied or dissatisfied. A dissatisfied customer may lead to a big drop in revenue, since they might take their business somewhere else. The final category is called customer incurred costs, which includes costs that a customer has because of the quality of the product being too low and therefore affect the customer operations.

3.2 Measuring CoPQ

There are different views on how to measure and collect data about CoPQ in a company and a few of these views are presented in this section. One similarity between the presented methods is that someone needs to be responsible for a certain activity quality costs, if it should be possible to improve and lower the cost for that activity (Zimak, 2000; Kent, 2016).

3.2.1 Assessment Method

The assessment method consists of having employees gather information about CoPQ by using different methods such as observations and interviews (Zimak, 2000). The assessment method is rarely used as the main tool to capture quality costs but can be used when there is a limitation of the scope to be analysed. It is also used as a pre-study to gain an estimation of the potential in the area before implementing a measurement system. To capture the quality costs, the employees need to be educated in how to use observations, surveys or interviews as tools to collect the data. Having someone analysing their co-workers in this way may have a negative impact on moral according to Zimak (2000). The author states that the main advantage is that there is no need to formalise the collection of data, and thereby it is more adaptable to the certain environment that is analysed.

3.2.2 Utilising Accounting System

If a company has a good accounting system in place which has cost codes that capture the activities that are driving the costs, it is possible to decide what codes should be incorporated into the different categories of CoPQ (Kent, 2016). The main benefit from using the accounting functions is that the cost is then factual and the emotions from people collecting the data is given less impact on the result. A disadvantage with this method is that it is harder to capture data about hidden costs, as they are often distributed as an overhead (Zimak, 2000).

It is important to understand what level of data accuracy is needed, since having complete and accurate information can be costly according to Kent (2016). The author further states that it can be appropriate to include non-financial numbers such as number of complaints, inventory accuracy or supplier performance to be able to understand the customer demand.

3.2.3 Time and Attendance Collection Method

Having different timecodes makes it possible to capture the time that is spent on certain activities by letting the employees log their time that they are spending on different types of quality costs. This method may result in an accurate picture of the cost of poor quality (Zimak, 2000). For this to work, all employees need to be trained to understand both the time codes as well as the categorisation used by the company, which means that there is a high start-up cost. There is also a need of having an audit system to make sure that the employees are logging their time the correct way according to Zimak (2000). The author states that the main advantage with this method is that the employees will be more involved in the quality work as their knowledge about the concept will increase with the education.

3.3 Lean Production and the Seven Wastes

Lean production was developed by Toyota and is a philosophy about how waste can be reduced in manufacturing and how production can be managed in an effective way. The concept of lean production consists of different methods on how to reduce wasteful activities and practices in processes (Nicholas, 2011). In lean there are seven wastes defined which should be reduced or in the best case eliminated to achieve an efficient system. Wastes in lean production are all activities that do not add value to the product produced.

Defects

One source of waste is defects and the severity of the defect can vary depending on where it is detected (Nicholas, 2011). If it is the customer that is noticing the defect it will most likely lead to a claim where the customer demands a new unit or reparation of the received unit. A defect might be detected before it reaches a customer through inspections and the impact of the defect may be less severe. However, inspections and fixing defects are also a waste of resources since labour and/or material must be used to fix the problems (Nicholas, 2011).

Material Handling and Transportations

Movement of goods between different processes might be considered waste if a transport could have been avoided or if the distance needed to move the items could have been reduced (Nicholas, 2011). The reason for this is that no value is added during transportation. The layout of the facility and the sequence of different process steps may affect the need for transports and should be organized in a way to limit transports as much as possible.

Inventory

Inventory is wasteful for many reasons according to Nicholas (2011). Having inventory means that capital is bound in the products which cannot be used for something else like improving the business. At the same time no value is added to products in inventory and the inventory also covers up for defects.

Overproduction

Producing without having demand for a certain item is considered to be a waste in lean production (Slack et al., 2010). Firstly, because it builds up inventory which is also a waste, and secondly because the items might not get sold at all. When demand is low it may be better to have workers idle than overproduce according to lean philosophy.

Waiting

Waiting concerns aspects like having to wait for orders, material, information, or the output from a previous step in the processing chain (Nicholas, 2011). An operator being idle due to repair of equipment or awaiting assistance is also considered to be wasteful.

Over-Processing

Certain processes may be unnecessary and are therefore wasteful (Nicholas, 2011). Over-processing an item to a point where customers do not demand it should be avoided. According to Arunagiri & Gnanavelbabu (2014) one reason for over-processing is that all processing may be viewed as value adding which often is not the case. If a process is complex, then there are quite often process steps which are not value adding and could be eliminated.

Motion

Motions that do not add value should be eliminated (Nicholas, 2011). Examples of wasteful motions are searching for items and loading/unloading of these items. Analysing the content of the work can reveal how much of a worker's time is value adding and non-value adding (Slack et al., 2010).

3.4 Trade-off Between Prevention, Appraisal and Failure Costs

Pyzdek (2003) presents two models for how cost of prevention, appraisal and failure interacts and relates to each other. In Figure 5, the models are shown and the author explains how the cost of prevention and appraisal have a trade-off with the cost of failure. As the quality level increases towards perfect quality, meaning that no defects at all will be delivered, the cost for appraisal and prevention increases drastically while the cost of failure approaches zero. The appraisal and prevention costs increase sharply since to ensure 100 % quality all items must be appraised. The total quality cost curve, which is the combination of the two curves, therefore increases drastically when the quality level is close to perfect according to this model (Castillo-Villar, Smith, & Simonton, 2012). This is shown in the left graph in Figure 5. The goal of a quality system is to have as low costs as possible and according to the model there is an optimal level of quality where the cost of failure, appraisal and prevention are balanced resulting in minimum cost (Kent, 2016). If the quality level is increased form this level, the cost of failure will decrease but the cost of appraisal and prevention will increase to a greater extent. Consequently, changing quality level from the optimum will increase the cost of quality and perfect quality is not appropriate according to this model.

The model was later revised after findings from further research according to Castillo-Villar et al. (2012). The research showed that the quality level can be increased to 100 % without the total quality cost starting to increase drastically. The revised model can be seen to the right in Figure 5. Pyzdek (2003) mentions that the first model can be misleading since it suggests that quality should not be improved after a certain point which may halt efforts to continuously improve. Both models are valid in different situations according to Castillo-Villar et al. (2012). Depending on the cost parameters when analysing cost of quality, the result may resemble both the first model and the revised one.

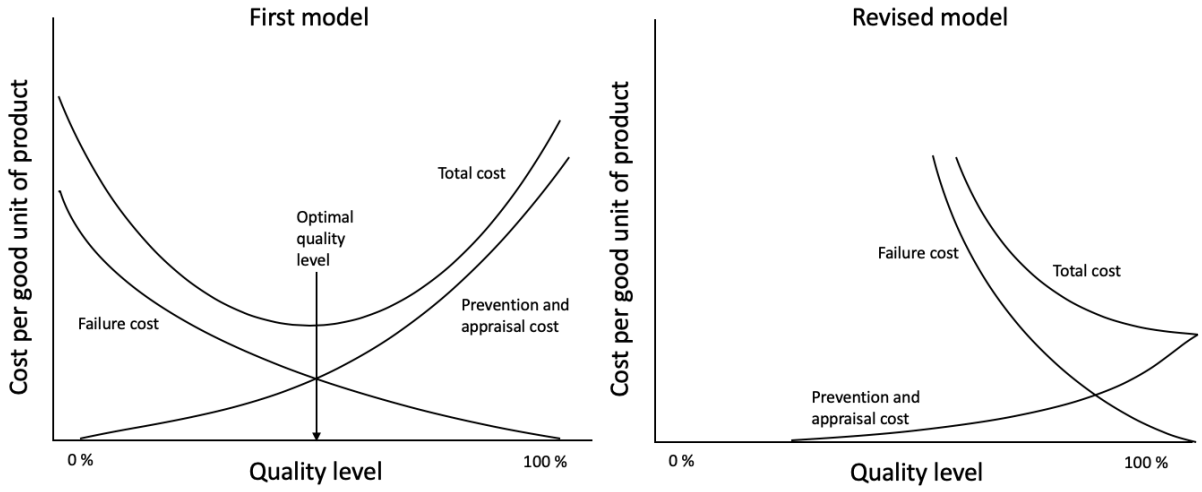

Figure 5: Model of cost of quality based on (Castillo-Villar et al., 2012).

3.5 Warehouse Operations

Warehouse operations consist of receiving goods, storage, order picking and shipping according to Gu et al. (2007). Receiving concerns manging incoming shipments meaning unloading and then moved to storage and shipping involves loading outgoing material on trucks. The main issues in these to processes are to ensure that there are docks available for the trucks and how to assign the incoming and outgoing trucks to appropriate docks according to Gu et al. (2007).

The authors mean that order picking is the costliest process of the warehouse operations and therefore this is explained in detail. Storage is also explained below.

Manual order picking usually consists of a number of steps that are quite similar for different warehouses (Grosse & Glock, 2015). The process is started by the order picker receiving a picking list with different items that are to be picked. The picker then walks or drives a forklift to the locations of the items on the lists and collects the required quantity either on a trolley, pallet or some other form of load carrier. The picker returns to the starting location or a packaging station where the collected items are packaged and then shipped off to customers (Grosse & Glock, 2015). Manual order picking is a labour-intensive activity and can be quite time-consuming according to Grosse, Glock, Jaber, & Neumann (2015). The authors state that more than 50 % of the operating expenses of a warehouse may be due to order picking, as a result of the labour-intensive nature of manual order picking.

Planning how an order picking system should work in a picker-to-part system consists of four major parts according to Grosse & Glock (2015). These parts are layout design, order batching, routing and storage assignment.

3.5.1 Layout Design

In layout design, decisions regarding the structure of the warehouse in terms of number and size of aisles are taken (Roodbergen, Sharp, & Vis, 2008). Other decisions in this phase includes determining how many of different types of aisles should be part of the warehouse. One type of aisles is a picking aisles which is where the pickers can access items and the number of picking aisles depends on how many items that are to be stored in the warehouse. Another type is cross aisle which is an aisle where a picker can shift from one picking aisles to another.

3.5.2 Order Batching

Order batching is used to limit the travelling distance for the picker in the warehouse and to better use the carrying capacity (Grosse & Glock, 2015). Order batching is done by splitting individual orders or by consolidating several smaller orders. If done appropriately order batching can reduce the total travel time to complete orders.

3.5.3 Routing

The sequence in which the order picker access and retrieve the required items for a picking order are defined by routing (Roodbergen & De Koster, 2001). An optimised route can reduce travel time and is important for efficient order picking. An appropriate route should be easy and convenient for the order picker to follow.

3.5.4 Storage Assignment

The last planning aspect of order picking, is storage assignment refers to how items should be assigned to different storage locations in the warehouse for the order picker to be able to access the items efficiently according to Roodbergen et al. (2008). There are several different policies for how the items can be assigned, three frequently used assignments are random, dedicated and class-based assignment.

Random Storage Assignment

With random assignment, items that arrive to the warehouse are assigned a random unoccupied location. Often, a high storage space utilisation is possible to achieve with random assignment but with higher transport times as a consequence. High space utilisation means that the locations in the warehouse are used to a high degree, but since items are not destined to certain locations

the picking route may increase. According to Grosse & Glock (2015) this assignment policy is appropriate to use when data about demand frequencies is not very reliable.

Dedicated Storage Assignment

The dedicated assignment means that each item has a specific location in the warehouse (De Koster, Le-Duc, & Roodbergen, 2007). A benefit of having a dedicated storage assignment is that the pickers become increasingly familiar with the positioning of items which may reduce picking times. Another benefit is that heavy items may be positioned in the start of a picking route while lighter items are positioned later which makes it easier for the pickers to stack. One drawback of a dedicated assignment is that the storage utilisation may be lower compared to other assignment policies according to De Koster et al. (2007). Since locations are reserved for one product, even though the product may be out of stock, the location cannot be used for another item. Furthermore, there also has to be enough space reserved to store the maximum amount for an item. Items may have to be moved to new location depending on changes in the demand of an item which can take a lot of time according to Battini, Glock, Grosse, Persona, & Sgarbosa (2016).

Class-based Storage Assignment

The class-based storage assignment means to assign items into different groups and then each group has a dedicated section of the warehouse (Grosse & Glock, 2015). Items are separated into groups by for example the frequency they are picked. Items in a group with high picking frequencies can then be placed closer to the starting point or packing station to reduce transport times (Grosse & Glock, 2015). Items may also be placed into classes depending on their characteristics. Items with similar characteristics are places in the same class and within each class the items may be sorted according to demand frequencies or be assigned randomly (De Koster et al., 2007). Each class can then be dedicated to a specific zone in the warehouse. However, De Koster et al. (2007) mention that for class-based storage to work efficiently, there has to be empty location in each class, otherwise inbound shipment cannot be assigned to their correct class. This problem may become even more apparent if there are a large number of different classes which all need to have available locations for new items. This may result in class-based assignment requiring more storage space and might lead to a lower storage space utilisation compared to a random assignment.

3.5.5 Order Picking and Human Factors

Grosse & Glock (2015) investigated the impact of learning on the performance of order picking and according to the authors, learning has a big impact on the picking efficiency and the performance of order pickers. Searching for the correct item is an example of were new employees spends a lot of extra time compared with experience pickers. The portion of temporary workers of the total work force affects the order picking performance since temporary works often do not have the time to gain experience about the processes (Grosse & Glock, 2015). Temporary workers may have longer order picking times than workers that are employed permanently at the company due to not having the same opportunity to learn. Learning regarding order picking might lead to improved performance and increased quality in terms of reduced number of picking errors (Grosse et al., 2015). Other human factors that may influence the order picking performance are motivation, fatigue, forgetting and boredom according to Grosse et al. (2015).

One way to increase motivation for employees is to have job enlargement (Rubenowitz, 2004). Job enlargement may be used in many types of businesses and not just for order picking. Having

job enlargement for employees, which means that skills required and the variety of tasks of a certain job are increased, have shown positive impacts on the employees motivation according to Berdicchia, Nicolli, & Masino (2016). For employees working at companies having monotone tasks like assembly on a production line, job enlargement provides an opportunity to do something different for the employees. Rubenowitz (2004) states that it is important to not only change a small part of the task, for example what is being picked, but rather changing the task overall. Changing the task could be from requiring physical labour to a task that requires the employee to use their cognitive abilities instead which could be that the employee takes part in planning of a process to complement the ordinary tasks during a work day.

3.5.6 Order Picking Errors

The quality of order picking is determined by how many errors that occurs from it according to Grosse et al. (2015). Picking errors happen when wrong items and/or wrong quantities of items have been picked or when items are misplaced. The picking error may occur due to the storage and picking methods and other factors such as coordination among pickers, tool used for picking and environmental factors such as noise and light. Perceptual and cognitive mistakes of the picker may also result in a picking error. Grosse et al. (2015) also mentions that there is an increased risk of making a picking error if similar items are placed close to each other.

Bateman & Ludwig (2004) mention that picking errors may be reduced by providing feedback to the picker and having an incentive program. Receiving feedback and implementing a tiered incentive program showed that the picking error reduced a lot compared to the initial picking accuracy before the incentive program. The incentive program was design in such a way that the monetary reward increased as the picker did fewer and fewer errors. The result of the incentive program was a reduction in cost since the savings from the decreased occurrence of pick errors was larger than the cost of the monetary reward of the incentive program. The motivation of pickers also showed an increase according to Bateman & Ludwig (2004). The authors also evaluated another incentive program where the pickers had to forfeit money for each picking error they made. This system did not work as well as the previously mentioned program. Bateman & Ludwig (2004) also point out that it is important to have strong support from managers for the incentive program to be successful and received well by the employees.

3.6 Sustainability

Sustainability and sustainable development are important issues and one definition that is often used is:

> "Sustainable d*evelopment that meets the needs of the present without compromising the ability of future generations to meet their needs*" (WCED, 1987).

One model for sustainable development is the triple bottom line model which is used to show the importance for companies to balance the pure economic performance with ecological and social performance as well according to Longoni & Cagliano (2018). The authors define social responsibility as taking care of employees, making sure that their welfare is positively affected by their work and taking part in community development. Reducing the consumption of natural resources, emission of different pollutants as well as not endangering the ecosystem is what is meant by ecological sustainability.

Previously some companies have viewed sustainability as a philanthropic activity which will not provide value according to Savitz & Weber (2014). However, the authors mean that a

company working with sustainability maximises the value of all its stakeholders, that is employees, customers, partners in business, society as well as the shareholders. To be sustainable means balancing the economic interest of the company with interests of other stakeholders that is societal and ecological interests (Savitz & Weber, 2014).

3.7 Synthesis of the Theoretical framework

In this section the theory presented in the theoretical framework is linked to the research questions of the thesis. How and what specific parts of the theoretical framework that have been used in the process to answer the three research questions are explained as well as the interaction between data collection and the literature study regarding what data was collected and how it was used. The double arrow between data collection and literature search indicates the interaction between them, that both processes are affected by and are affecting the other during the project.

3.7.1 Theory and Data Collection for Research Question 1

Theory and data collection methods related to answering research question one that is, identification of quality deficiencies is presented in Figure 6.

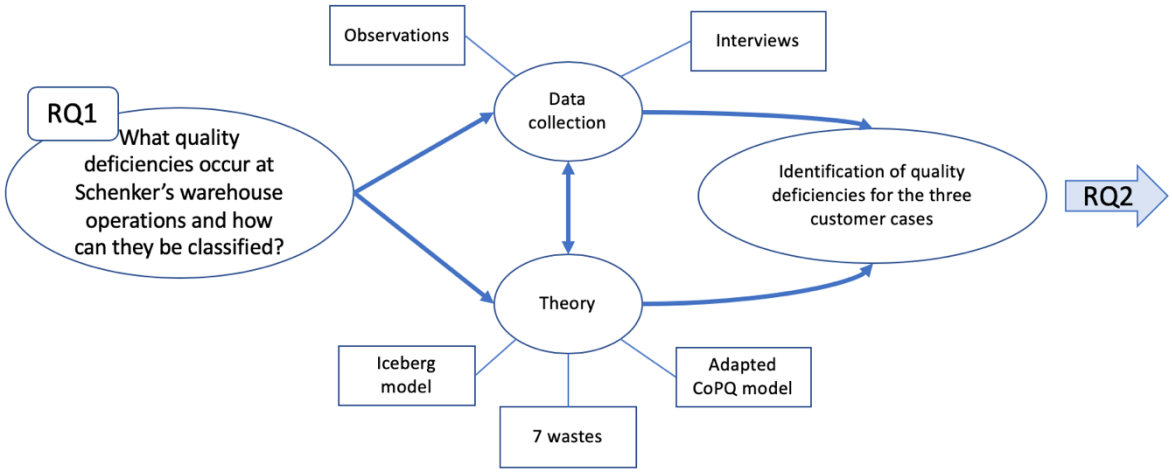

Figure 6: Theory and data collection methods used to answer research question 1.

The concept of CoPQ (subsection 3.1.2) with prevention, appraisal and failure costs were also used to understand what types of quality deficiencies that occur in the warehouse operations. It was also used to structure the identified deficiencies into a classification. Not all quality deficiencies were identified through interviews. The iceberg model (subsection 3.1.1) explains that a large portion of quality costs are hidden and may be incorporated in current routines and might not be considered as wasteful by the employees. To identify these costs, observations of the warehouse operations were also needed and if any operation seemed to be non value adding, it was further investigated in interviews. The result gained from answering the first research question was a table of quality deficiencies. This table was used as used as the basis for what should be quantified in answering the second research question.

Harrington's (1999) model of CoPQ which is presented in subsection 3.1.2 was used to classify identified quality deficiencies in the warehouse operations. Appraisal costs, prevention costs, non value added and internal errors are included in the classification model used for the thesis while external failure costs and all of the indirect costs are excluded. Indirect costs and external failure costs are excluded from the classification since the purpose of the thesis is to identify,

quantify and improve the quality deficiencies that occur internally in Schenker's operations and the external impact of the quality deficiencies are not analysed.

As was mentioned in the introduction, CoPQ is a concept which usually refers to costs in monetary terms but since Schenker wants to know how much time is spent on quality deficiencies the time-consumption of different deficiencies will be collected and not translated into costs in the CoPQ model. The CoPQ model is used to classify and structure the identified quality deficiencies and is then used to present the quantified time consumption. The adapted model which is used for this thesis is shown in Figure 7.

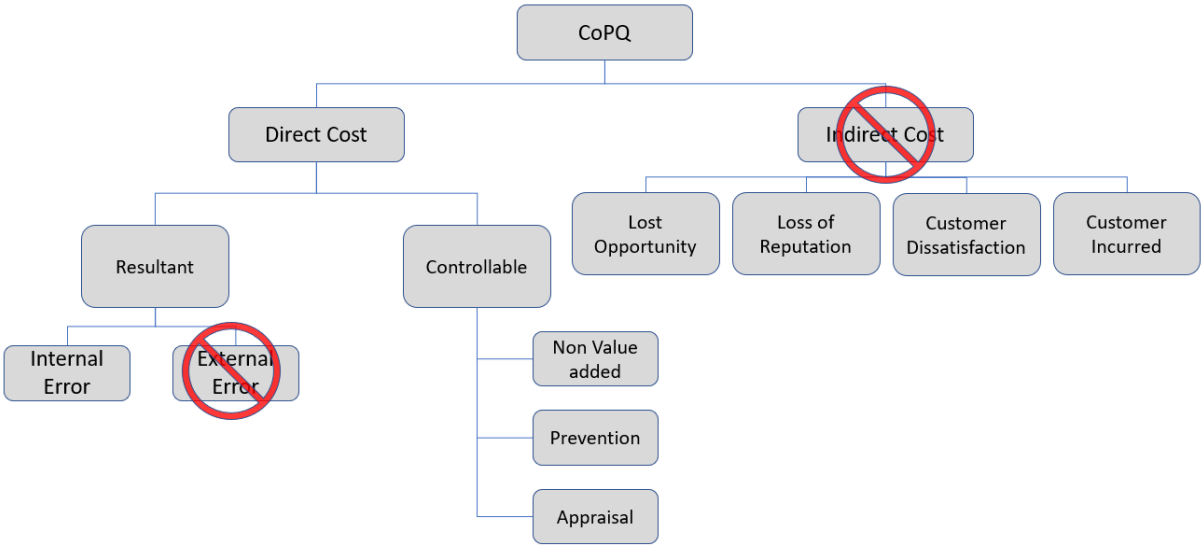

Figure 7: Adapted version of Harrington's (1999) model of CoPQ. External and indirect costs have been excluded.

Harrington (1999) defines the non value added category of CoPQ as activities that do not add any value to the system. For this thesis, the category non value added includes the activities which are part of the seven wastes of lean production, presented in subsection 3.3.1. The seven wastes mentioned in the lean production philosophy are wastes which may occur in a manufacturing company and may not be directly applicable for warehouse operations. Overproduction and inventory are not applicable to warehousing and are therefore excluded from the non value added category. Activities performed by Schenker which causes waiting, transportation, motion, over-processing and defects which could have been avoided are categorised as non value added in the model.

3.7.2 Theory and Data Collection for Research Question 2

In this subsection, theory and data collections methods that are related to the second research question are presented, in Figure 8.

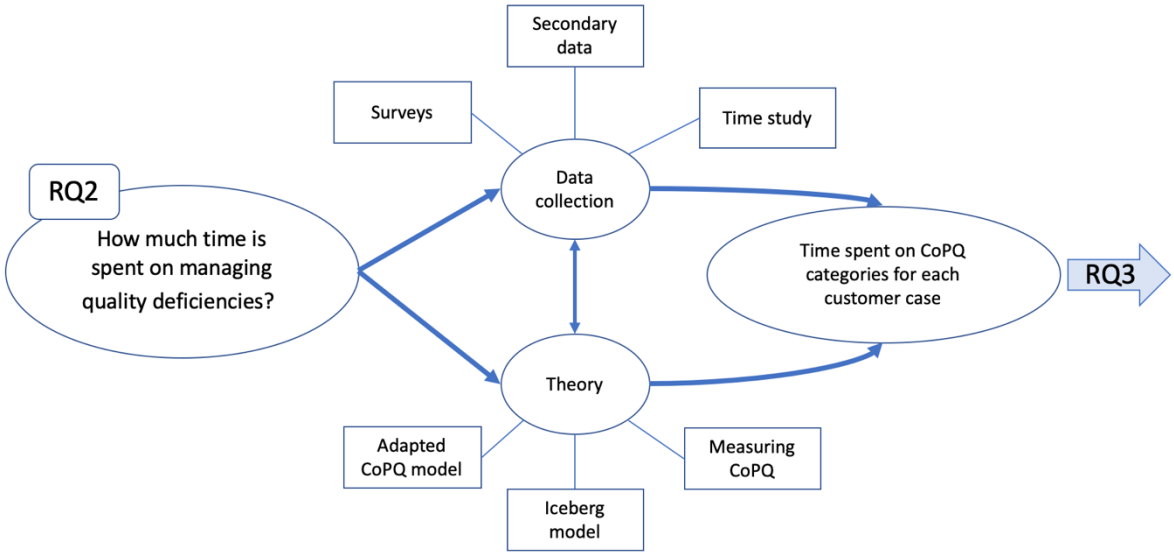

Figure 8: Theory and data collection methods used to answer research question 2.

The theory presented in section 3.2 about measuring CoPQ was used to create the first draft of the survey and for the retrieval of data from Schenker's databases. The theory presented in 3.2.3 about time logs was used as an inspiration for the design of the first draft of the survey. The collected data was then structured according to the adapted version of Harrington's model presented in the previous subsection.

The iceberg model was kept in mind during the data collection as it helped to understand the accuracy of the collected data and be aware that new hidden quality deficiencies may occur in the survey that were not mentioned in the interviews. Therefore, daily contact with the employees filling out the survey was determined to be necessary.

3.7.3 Theory and Data Collection for Research Question 3

In Figure 9, methods and theory related to research question 3 are presented.

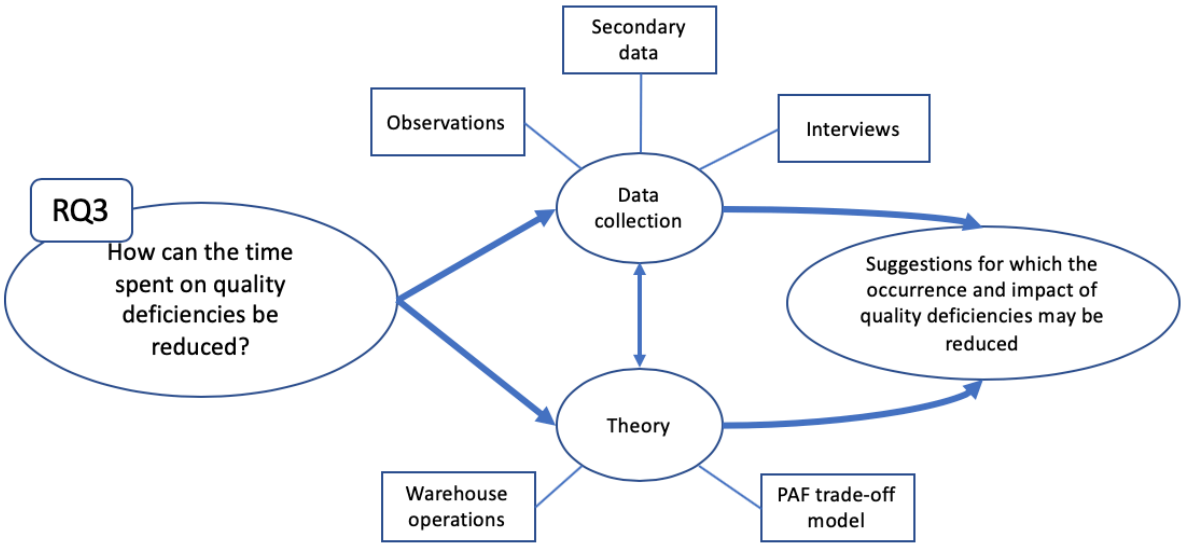

Figure 9: Theory and data collection methods used to answer research question 3.

In this phase many sources of data were used to be able to first analyse the results from RQ2 and then to be able to come up with improvements regarding how the time spent on handling deficiencies can be reduced.

To analyse what could be improved, literature regarding storage assignment and order picking were used, to be able to understand why some of the quality deficiencies occur and the difference between the customer cases.

The trade-off model for prevention, appraisal and failure costs (subsection 3.5.3) was applied to the collected data regarding inspections. How much time is spent on inspections was compared with the number of failures that are found to determine the value of the inspection. By comparing the failures detected and the time spent to inspect it could be determined whether current levels of inspections were appropriate or if they should be reduced or increased.

4. Customer Cases

In this chapter the three customer cases are described. In the first section, the interactions between customer, end customer, suppliers are explained as well as the role of Schenker Logistics. Since most of the processes are quite similar for the three customers, a general description of the warehouse operations is introduced. There are some roles in the warehouse operations that are supporting the processes, and these are control tower, production support, group leaders and supervisors. After this description, any major differences in the processes between the customers are explained.

4.1 Definition of Actors Involved in the Warehouse Operations

A definition of what is meant by customer, supplier and end customer is presented here. Customer is used to describe the companies that have hired Schenker to manage their inventory and the three customers studied in this thesis are called customer A, B and C. The companies that Schenker delivers items to, that is the customers of Schenker's customers are defined as end customers. Suppliers are defined as the companies producing and delivering items to Schenker's warehouses. For customer B, the customer is the supplier as well. It is only the internal operations at Schenker that are analysed in the thesis, which has been mentioned previously. A visualization of this definition is provided in Figure 10. The dashed rectangle shows the boundary between Schenker and the customer, end customer and suppliers.

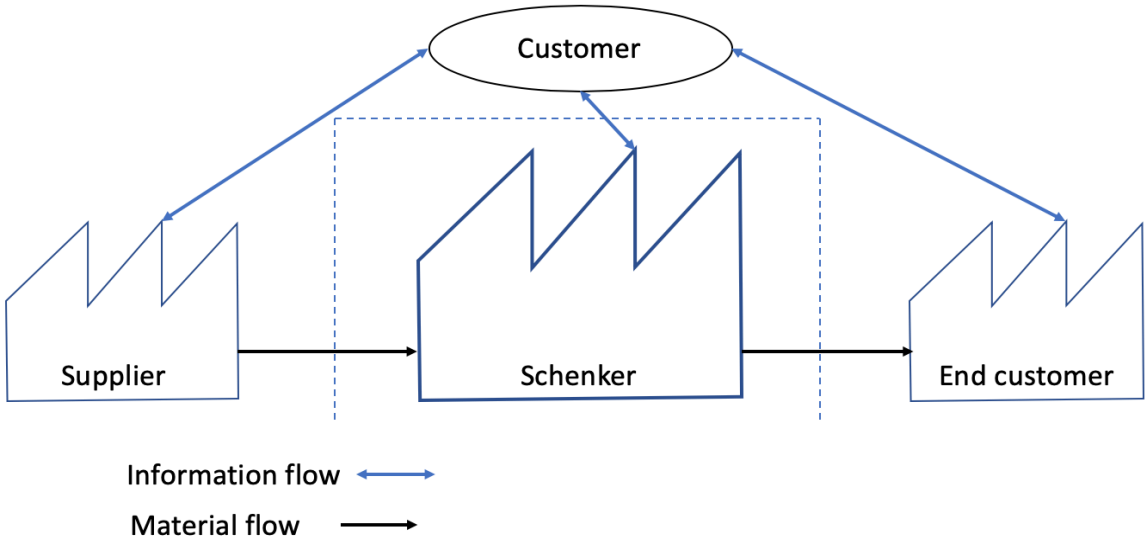

Figure 10: Visualization of the material and information flow where Schenker is a part

Schenker mostly communicates with the customer and not so much with the other actors. If there are any claims from end customers these are received from the customer since the end customer does not contact Schenker directly. If there are any returns from end customers, the end customer either sends the items to the customer who in turn sends them to Schenker, or directly to Schenker.

For all three customer cases the operations have been separated into two parts, inbound and outbound since these processes have a defined boundary between them. The inbound process includes all activities that take place to receive goods so that the goods can be stored and be made available for picking or moved to a buffer location for later use. The outbound operations include all activities that are involved in making sure that the goods are picked from the warehouse and shipped to end customers.

4.2 General Flow Description

The general process steps of the flow and the activities performed at each step are presented in Figure 11. Customer specific processes are described later in section 4.5. The responsibilities of the two support functions are also described.

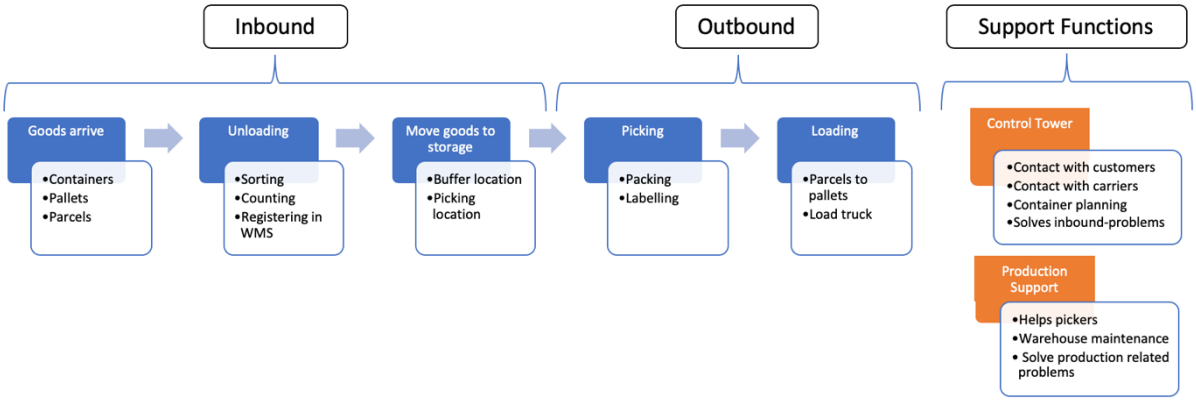

Figure 11: Description of Warehouse processes

4.2.1 Inbound Process Description

In the unloading process step the arriving goods are unloaded and then sorted, counted and registered in the warehouse management system (WMS). Goods can arrive in three different types of load carriers, in containers, on pallets or as parcels. Depending on in which way the goods arrive the unloading process is slightly different. The goods that arrive in containers are usually in a large number of parcels which are part of different purchase orders and needs to be sorted. The parcels are sorted onto pallets so that the same article ends up on the same pallets. The suppliers may also send mixed parcels, which means that there is more than one type of product in a parcel, and this also needs to be sorted. When the goods have been sorted, the goods are counted and checked against the delivery note. If everything is in order, the goods are registered in the WMS and labels are printed and placed on the pallets, completing the unloading process. If there is anything that is incorrect with the inbound order, Control Tower should be contacted.

Inspections of the arriving goods are also conducted in the unloading process and consist of visual inspection to look for any damaged goods and sometimes of a humidity test, depending on the items delivered.

With the unloading process completed the next step is to move the pallets to the correct location in the warehouse. There are two options for where the goods can be stored, either in buffer or directly at a picking location. For the majority of the flow of goods, a confirmation number is used before placing the pallet at a location which is in place to minimize the mistakes in the inbound process. Each location has a specific confirmation number which has to be scanned for the system to accept the movement in the warehouse, and thereafter update the WMS.

Thereafter the goods are available in the system on the new location. There are also two different areas in the warehouse, which are floor level and mezzanine. The mezzanine is the second floor of the warehouse. The main differences between the areas regarding the inbound process is that goods destined to the mezzanine needs be lifted to that level. The goods stored on mezzanine are generally smaller and lighter items and are picked using trolleys instead of forklifts.

4.2.2 Outbound Process Description

The outbound process is performed in two separate areas, mezzanine and floor, which have the same activities, picking and loading. Picking orders arrive from end customers and usually consist of a number of different items. The employees drive/walk through the warehouse collecting items for several orders at once, in a multi order picking strategy. The picking is conducted by using a hand scanner to either scan the location or the item inside the parcels (it depends on the customer). The picker reads the information about the amount, and then the picker scans a label that is connected to the order it should be picked to. There are different solutions on what the picker is putting the items in, it can either be a box that is only used during picking, a box that will be sent to the end customer or directly on a pallet. When a picking round is completed, the picker takes the goods to a packing station. At the packing station, the goods are labelled. The goods are then sorted to the correct carrier´s pallets and moved to an outbound area. Then the carriers arrive, and the goods are loaded onto trucks and the driver signs of that they have received the goods and then the parcels are no longer the responsibility of Schenker.

4.3 Support Functions

There are two functions in place that are supporting the warehouse operations to facilitate the work for the warehouse operators and also acts as a middleman in the communication to the customer. These are called control tower and production support, which are described in this section.

4.3.1 Control Tower

Control tower (CT) is mostly responsible for managing contact with the customers and carriers. If there are problems with an arriving shipment CT will manage the contact with customer and investigate what has gone wrong and determine what to do with the incorrect shipment. If the employees working with unloading detect a problem, for example incorrect amount in the shipment or missing delivery note then CT is contacted, and if it is a major issue the shipment is set aside until CT has contacted and received instructions from the customer. CT also manages the contact with carriers, books transportation and plans the arrival of trucks. The role of the CT function is also to act as a middleman between the warehouse operations and the customers.

4.3.2 Production Support

The second support function, production support (PS), are more directly involved in the warehouse operations than CT and is contacted if any problems occur, both in inbound and outbound processes. Problems that inbound might face that require PS assistance are goods have been moved to the wrong location or pallet height corrections. For outbound, PS assist the pickers if they encounter any problems. PS may have to adjust and check the balance of items on different picking locations when pickers have discovered an empty location and many other deficiencies that are described in chapter 5.

Managing claims from end customers is also part of PS responsibilities. Claims from end customers can have occurred due to many reasons and PS investigates what has happened and solves any issues and updates the system.

4.3.3 Group Leader and Supervisor

A group leader (GL) is a role in warehouse operations which is supposed to manage the staff in the process. They are responsible for either inbound or outbound and manage a group of 5-15 people. The main task of the GL is to divide the workload among the employees. They are also

in charge of managing some part of the WMS for example managing when to open up a new departure, to ensure that the workload is levelled out and is finished in time. They also communicate with the supervisor about the planning of staff needed for the next day.

The supervisors are responsible for all the different processes in the warehouse operations, including inbound, outbound and PS. One of the main tasks is to manage staff and make sure there is an appropriate number of employees to meet the goals of the day at each process.

4.4 Storage Assignment and Morning Meetings

In this section, the storage assignment policy for the three customer cases and the routine regarding meetings are presented.

4.4.1 Storage Assignment Policy and Replenishment of Picking Locations

For customer A and B, a class-based storage assignment is used, as described in subsection 3.5.4. Customer C on the other hand uses a dedicated storage assignment for the picking location at floor level and are locating the buffer stock in as close proximity of the picking location. This is performed to reduce the time that is needed for replenishments.

Replenishment of picking locations is performed in the same way for customer A and B, where the WMS creates replenishment orders when the employees initiate a new departure or manually push replenishment orders. This is performed to make sure that the pickers will have the articles available when they are needed and not having to wait for replenishments. Since customer C is using fixed picking locations it means that a replenishment can only be performed when a location has been emptied or that there are only a few items left. Therefore, the WMS creates an automated replenishment order when the inventory level reaches below a decided level. The buffer storage assignment is random for customer C and is based on the smallest distance to the picking location.

4.4.2 Morning Meetings

A morning meeting is a meeting where everyone in a workgroup participates and relevant information is shared to make sure that issues or problems are shared among the employees. It is also a platform to follow up daily productivity. The meetings usually last between 5-10 minutes each day.

4.5 Differences Between the Customers

In this chapter differences between the customer cases are described to clarify that there are customer specific adaptations in the process flow, which affect what types of problems that may arise. The chapter is concluded by showing a table of the difference in size.

4.5.1 Customer A

The specific process steps that are unique to customer A are presented in this subsection. Customer A’s warehouse operations are performed in a shared site, which means that there are other customers in the same building. This means that equipment can be shared between customers operations and also it is possible to transfer warehouse operators between customer assignments.

Consolidation

Consolidation is an aspect of the flow that is specific for customer A. This means that some parts of the goods need to be consolidated, as a consequence of it being picked on both floor level and mezzanine. Consolidation orders from mezzanine and floor should be completed at a predetermined time otherwise the consolidation cannot be efficiently completed and thereby time might have to be spent trying to find the right parcels to consolidate.

Bonus Malus

In the contract between Schenker and customer A it is stated that there is a bonus malus system connected to four aspects of the warehouse operations. These are based on inbound on time, stock accuracy, picking accuracy and order ready for shipment. This means that there is another incentive compared to the other customer cases regarding on what to prioritize.

Production Support

The production support function consists of four employees for customer A. They are divided into supporting the mezzanine (2 people) and the floor (2-4 people). On the mezzanine part, the two people are working close together and thereby helps each other on every task that they are given, compared to the floor level, where PS, are working a bit more independently and the goal is to always have someone at their workstation to be able to help the pickers faster.

4.5.2 Customer B

The specific process steps that are unique to customer B are presented in this subsection. Customer B is also located in a shared warehouse.

Two Inbound Areas

The inbound process for customer B is slightly different from the description in subsection 4.2.1 regarding mezzanine and the floor level. When goods arrive from suppliers there are pallets with parcels containing many different items. The group leader or operator at inbound will decide whether the pallet should be lifted up to mezzanine or stay at the floor level based on a visual inspection of the items and on their experience. If a majority of the items are small then the pallet will be lifted up to mezzanine, otherwise it will stay at the floor level.

Production Support

For customer B, only one employee has the role of PS, which means that there is need of having more people knowing how to perform some of PS tasks, to cover for sickness and vacations and currently an employee is being trained to learn the task of PS. The group leaders have also learnt to solve some of the quality deficiencies, but it also means that they have to stop their own tasks to solve issues.

4.5.3 Customer C

The specific process steps that are unique for customer C are presented in this subsection. The site is dedicated for customer C, meaning that no other customers share the warehouse.

Relationship Between End Customer and Customer

Figure 10 in section 4.1 is not completely accurate for customer C. Since customer C owns their own stores, they are both the customer and the end customer. The customer has decided to not conduct any inbound delivery checks at the stores, therefore picking errors are rarely detected and reported to Schenker. Little feedback on the picking accuracy is received from the end customer and inspections of the order picking are conducted by Schenker to be able to show the customer the picking accuracy as well as being able to give pickers feedback. The aim is to

conduct the inspection two days each month. This means that the pickers do not receive as much feedback on their performance compared with the pickers for the other customers. However, customer C also have a small part of their orders sold through an e-commerce channel. For these orders the end customer will be the user of the products and they are more likely to make a claim if any picking errors occurs, and this will give feedback to the pickers.

Rotation of Staff at Production Support and CT

For customer C, a number of employees share the responsibility of working as PS. Four employees rotate and work one week at a time as PS. The rest of the time these employees have other responsibilities in the warehouse such as order picking or unloading. The CT function also has this rotation. By rotating the employees working as CT and as PS there is almost always someone available to manage these functions even if someone is ill or is having vacation. If CT or PS has much to do certain days, then most of the time there is someone who can support them.

4.5.4 Sizes differences

There are a few differences in terms of size between the customers presented in Table 1. SKU stands for stock keeping unit that is stored in the warehouse. The order lines shown in the table are for the outbound process. The hours that is spent per day is an average during a ten-day period and consist of both hours spent on inbound and outbound processes. The final column shows the number of employees working at production support.

Table 1: Comparison between the customers.

Customer	Order lines per day	SKU:s	Hours per day spent on Inbound and Outbound processes	Number of PS
A	6 930	33 401	267	4-6
B	3 032	6 815	190	1
C	5 531	7 402	320	1

As can be seen in the table, there are differences between the customer cases when it comes to the four variables presented. This data may vary over the year due to seasonal changes but still provides an accurate indication of the difference in size.

5. Identified Quality Deficiencies

In this chapter the identified quality deficiencies are presented answering the first research question of the thesis: "*What quality deficiencies occur at Schenker's warehouse operations and how can they be classified?*". First, quality deficiencies that are common for all three customers are presented separated in inbound, outbound and miscellaneous activities. This is followed by customer specific deficiencies.

5.1 Classification of Quality Deficiency

The identified quality deficiencies are classified according to the adapted version of Harrington's (1999) model of cost of poor quality (CoPQ) as was mentioned in subsection 3.7.1. The model has been adapted to be appropriate for the scope of the thesis and some of the areas of the model have therefore been excluded. The indirect costs category which includes lost opportunity, loss of reputation, customer dissatisfaction and customer incurred have been excluded since it is only the internal processes and quality deficiencies that are included in the project. External errors in the resultant category has also been excluded since these are errors that only affect the end customer.

Certain activities like inspections are conducted by Schenker according to the contract with the customer. The time spent on performing these inspections are not included in the model even though according to Harrington, inspections should be considered to be an appraisal cost. Inspections that are performed by Schenker which are not enforced by any contract are included as appraisal cost. Value added services (VAS) are excluded. Table 2 below show the classifications which are used to classify the identified quality deficiencies.

Table 2: Classifications of cost of poor quality used for the identified quality deficiencies based on Harrington (1999).

Classifications	Description
Appraisal	Time spent on appraising the quality of operations, for example inspections
Non value added	Activities that do not add any value to the operations which may be a result of a deficiency. For example, transportation, waiting, motion, defects and over-processing
Prevention	Activities that are performed to reduce the occurrence of internal errors in the operations.
Internal error	All errors that need to be handled with extra activities for example picking errors.
Excluded	Deficiencies that are outside the scope of the thesis or are part of the contract between the customer and Schenker.

All quality deficiencies may be considered to be non value added but as is presented in Table 2, non value added concerns activities which has to be performed as a result of other quality deficiencies and five of the seven wastes of lean production are the activities which are considered to be non value added.

5.2 Quality Deficiencies in the Inbound Process

The quality deficiencies that occur in the inbound process are presented in this section. These deficiencies may cause problems later in the outbound process.

5.2.1 Switched Labels

One quality deficiency in inbound that may take a long time to solve is when employees switch labels at the inbound flow and place the labels on the wrong pallet or parcel. The consequence is that it may first be discovered by pickers when they are scanning the item inside the parcel at the picking location and receive an error message. The pickers then need to contact PS, who has to investigate and locate the right items in the warehouse before the picking order can be finished. PS tries to locate where the right items are by going through the purchasing order and PS may have to inspect all parcels or pallets of that purchasing order to be able to correct the switched labels.

In the flow to the mezzanine for customer A, switched labels may lead to the wrong item being picked and delivered to the customer because the picker scans the location and not the article on the location. The issue with this quality deficiency is that it affects at least two articles, as the staff at the inbound process are switching labels, but the switched labels could affect many more items. If the turnover is high on the incoming goods, it means that there is a risk that all switched labels already have been delivered to the end customers, leading to many claims.

Switched labels seldom occur but is said to be related to the amount of new staff working in the inbound flow. The pickers are the ones that notice the switched labels when they cannot scan the articles and then needs to contact PS for assistance. PS then needs to make sure that the problem is solved by checking and updating the information in the warehouse management system (WMS).

Switch labels may lead to shortage of inventory (subsection 5.3.5), surplus inventory (subsection 5.3.4) and/or claims (subsection 5.3.7). Therefore, the time spent on managing this deficiency at mezzanine for customer A will be included in these three other deficiencies.

Classification: Internal error

5.2.2 Supplier Error Inbound

The consequences in the inbound process caused by suppliers are that it may lead to extra administrative tasks and extra counting time if the goods delivered do not match the information on the delivery note. If this occurs, the inbound employees have to write this down on the delivery note, scan it to CT who forwards it to the customer. The customer can then update their business system about the amount delivered.

Classification: Appraisal

Another possible supplier error is that the documentation like delivery notes is missing or that the timeliness of the incoming deliveries is off. This may lead to the employees having to wait before they can start processing the inbound delivery. If this occurs, GL will contact the customer, and if there is nothing else to do during the waiting period, the waiting time will be billed as VAS.

Classification: Excluded-VAS

5.2.3 Height of Pallet Error

When the inbound employees decide what height is needed on the location for incoming goods, they may choose a location with wrong height for what is needed for a pallet. This can result in two problems. Firstly, it may be that the chosen location does not have enough room, which means that PS needs to correct the problem and move the pallet to another location. Secondly,

the pallet may also end up at location which has too much room available, which means that the utilisation of the storage of the warehouse will be lower, and that bigger locations will be used by pallets that could have been stored at other locations.

Classification: Internal error

5.3 Quality Deficiencies in the Outbound Process

The common quality deficiencies identified related to the outbound process for the customers are presented in this section.

5.3.1 Picking Errors

The reasons for making picking errors are many. For example, a picker may put the item in the wrong parcel during the picking process since they are picking multiple orders during one picking round. It is also possible that the picker is not careful enough when it comes to counting the number of pieces that should be picked to each order. In some cases, it may also occur that there are wrong items on the location and since the picker only scans the first item of each product, it means that there is a risk that the picker takes the wrong items. This may be caused by errors performed at inbound or due to a supplier error. Picking errors are often detected by the end customer who then claims that the items delivered are wrong. Sometimes the picking error is detected by the picker and the picker will then have to repack and count the order to correct the error. The time to manage picking errors that are detected by Schenker was collected in this category, while undetected error, that is picking errors detected by the end customer, was collected in the handling claim's category 5.3.7. For customer C opened store packs which is explained in subsection 5.7.1 may also cause a picking error.

Not all picking errors are detected either by Schenker or the end customer, this can lead to either surplus inventory or shortage in inventory, and the time to manage this will be included in the time for each of the two deficiencies.

Classification: Internal error

5.3.2 Sorting Errors

When the orders have been packed and the boxes have been closed, the boxes are sorted onto different pallets that will be sent with carries. Sometimes the staff in this process may misplace an item on a pallet and it might take a long time before the box will be delivered to the end customer as it needs to be found and then delivered to the right customer. The same issue may also happen for whole pallets that are sent with the wrong carrier. When this happens, the customer contacts Schenker by filing a claim and Schenker then needs to investigate what went wrong and take actions on how to manage the sorting error.

Another thing that can happen on the outbound area is that the driver responsible for picking up the delivery takes the wrong pallet. This means that another delivery is incomplete and needs to be managed. If a driver cannot find the pallets that he/she is supposed to pick up at customer C, GL has to look at video recordings of the outbound area to find where the missing pallets are.

Classification: Internal error

5.3.3 Supplier Error Outbound

As mentioned in subsection 5.2.2, supplier errors may have large impacts on the warehouse operations. For the outbound process it can mean that the wrong number of products are sent to

the end customer as a consequence of faulty information and labelling of the boxes. This means that the end customer will most likely claim that they have gotten the wrong number of items. Another consequence is that it may lead to wrong information about the inventory levels of the specific product and thereby require the picker to contact PS. This occurs if the parcels delivered to Schenker contains fewer items than stated on the label. The opposite could also occur, that a parcel contains more items than stated on the label. The consequences of this would be that there are surplus or a shortage of items that have to be to be handled by PS. Supplier error will therefore be included in these two deficiencies (subsection 5.3.4 and 5.3.5).

Classification: Internal error

5.3.4 Surplus Inventory

When warehouse operators find items that are on locations that they should not be on, for example locations that should be empty, they move the items to PS. PS will have to go through this pile of items and find the reasons for why the item is in surplus and then put the items out on a new location or at an existing location if the item has one. Then the inventory level for the item is updated in the WMS. This step needs to be performed before they start handling claims to be able to analyse what the reason for the claim is. If this step is not performed before managing claims, it could be that picking errors would not be accepted as there are no indications that there is wrong inventory balance on the picking location.

Classification: Non value added

5.3.5 Shortage in Inventory

The inventory balance might be incorrect at a picking location and this is discovered by pickers. When pickers are to collect a number of items at a location, they might discover that there are no items or too few at that location and they then have to report to PS. PS will then search for the item in the WMS. There are four different possible outcomes of shortage in inventory: the item has another picking location available, the item is available in buffer, the item is out of stock or refilling of the location is on the way but has not been moved to the location yet.

Classification: Non value added

5.3.6 Labels Do not Print

Labels might not get printed in the packaging stage. If this happens the package will be put aside until the labels can be printed. If the labels cannot be printed for a long time it might be difficult to put the correct label on the correct package since there will be a large number of packages without labels and it may require a long time to sort out. The risk of sending the package to wrong end customer increases as well. Usually PS is contacted if labels cannot be printed. Usually the extent of the printing problem is smaller, a few parcels per day may have this issue. This problem may be caused by the internal IT system, or that the customer has sent the wrong information to Schenker regarding where to send the deliveries.

Classification: Internal error

5.3.7 Handling Claims

When end customers are dissatisfied with the products delivered to them, they make a claim to Schenker. Picking errors or supplier errors are reasons for end customers to make complaints, which usually means that the end customer has not received the items they had ordered. If an item was missing, then a new order is also created and will have to be picked. End customers

sometimes make claims if they receive too many of an item and send the surplus item back. PS is responsible for managing the claims and this is performed by trying to figure out what has gone wrong by going through the information in the WMS as well as the physical locations to determine the cause. If the investigation shows that the customers claims is correct, the claim is accepted.

Classification: Non value added

5.3.8 Missing Customs Documentation

Some of the end customers of Schenker are not in the European Union and when shipping orders outside of the EU, documentation about contents of the shipment is needed in the customs. Sometimes these are forgotten, and the shipment will not pass through the customs and the delivery will be delayed. Schenker is notified by the customs that the documentation is missing and the documentation for the order is sent by CT.

Classification: Internal error

5.3.9 Managing Wrong Volume Data

In the WMS master data, the product's volumes should be defined. If the volume is incorrect it may cause problems in the order picking. If the volume is very different in reality compared to what is stated in the WMS, it means that the picker will either have too much space in their boxes for the order, or too little. If this is noticed, the pickers are supposed to contact PS who can then update the information about the volume in the WMS.

Classification: Internal error

5.3.10 Pallet Collapse in Racking

When pallets are handled inside the warehouse, sometimes a pallet is misplaced or put in the racking in an unsafe way. This means that the pallet may fall down or that a nearby pallet is moved which can cause it to fall. If this occurs someone needs to handle the pallet and rearrange the pallet and make it safe again to store it. There can also be situations where boxes on a pallet are weak or the goods are unstable and may fall down. If this happens, it also needs to be handled to make the workplace safe again. Goods may also be damaged if the pallets fall from their racking or if the employees are not careful when moving them.

Classification: Internal error

5.3.11 Identification Problem

Sometimes the barcode on a parcel cannot be scanned by the order picker and the picker will not be able to pick that item. The problem might occur due to the inbound staff adding the wrong article number label to the WMS for that article or because the system is not working as intended. When order pickers encounter this problem, they have to contact PS and get help with the problem before they can continue with their picking route. This also takes time for PS to manage since PS has to print new labels for the item and attach them. The picker has to wait while PS solves the issue and print new working labels.

Classification: Internal error

5.3.12 Picking Inspections

The picking accuracy is sometimes assessed using inspections of completed picking orders. The inspections are mostly conducted to ensure that new employees have learnt to pick correctly,

especially for customer A and B. For customer C picking inspections are used to a greater extent since the inspections are also used to determine whether the picking accuracy is above the required level stated in the contract with the customer. As was mentioned in subsection 4.5.3, customer C have their own stores, and they have decided to not check whether the received shipment contains all items that were ordered. The inspections are thus a way for Schenker to show customer C that the picking accuracy is sufficiently high.

Classification: Appraisal

5.3.13 Rearrange Pallet/Parcels

During the picking route it can sometimes be difficult to place all the articles on an appropriate location, and therefore the picker may have to re-arrange the articles when more articles are picked. Repacking is said to be happen with higher frequency for newer staff.

Classification: Non value added

5.4 Miscellaneous Deficiencies and Activities

In this section activities which are performed to reduce the occurrence of quality deficiencies are presented. Wasteful activities which have to take place due to a quality deficiency are also presented here. These activities may occur in both in- and outbound processes.

5.4.1 Education of Staff

When new staff is hired, they need to be educated into the processes to avoid making mistakes as well as to become an efficient employee that can contribute to the company's success. Education is needed for two purposes, when a new person has to be trained or it can be a strategic decision to widen the competences among existing employees to be able to cope with vacations and sickness. The education is performed by having an experienced employee working closely to the new employee the first day. The teacher shows how to perform the specified task and other routines in the warehouse. During the education, two people are needed to perform one employee's work tasks.

Classification: Prevention

5.4.2 Transportations

When the pickers encounter problems that they cannot solve, they need to go to PS or the group leader who can help with the problem. This means that they need to either drive with the forklift (floor level) or walk (mezzanine) to PS or GL and they also might have to wait until the problem is solved which can take a while. To understand which deficiencies that require transportation, PS was consulted.

Classification: Non value added

5.4.3 Waiting

Waiting for support is a wasteful activity. The pickers may have to contact PS if they encounter some of the deficiencies and the pickers might have to wait for PS to solve the issue. If PS realises that it will take quite a long time to fix, then they will tell the picker do to something else, like cleaning and remove waste packaging material, which means they need to move to a station where they can change which activity they are logged into. Which deficiencies that may cause waiting were further investigated.

Classification: Non value added

5.4.4 Warehouse Maintenance

There is a need to have the right type of storing locations available to be able to have an efficient inbound process, therefore PS needs to rearrange pallets and goods in the warehouse and this activity is called warehouse maintenance. This also affects how efficient the picking process can be, since having the right goods at the right location can reduce the picking time needed to complete an order by having the goods more easily accessible. This is usually performed in a proactive manner, meaning that there should be a number of available locations of each class available at all times.

For customer C the picking locations are fixed, which means that the picking location for a new item is decided depending on the information about the characteristics of the product such as height, width, length and weight. This is managed by PS who tries to put items on a suitable place on the picking route which makes it easy to load products onto a pallet. For example, heavy and bulky items are placed at the start of the picking route and items that have strange shapes or are fragile are placed later on the route. If items have been placed at a non-optimal location, the location has to be changed which means that PS needs to move the items to another location.

Classification: Prevention

5.4.5 Damaged Goods

If goods get damaged in the operations, it should be moved to the PS workstation. There the goods will be stored until a decision is made from the customer. Damaged goods are not very common for customer A because of the type of goods that are managed.

For customer C there are special circumstances that affect how damaged goods are handled. If it is in small amounts that are damaged, the pickers are allowed to throw the goods away directly and fill in a form about the amount discarded. This is to make it possible for PS to change the inventory balance in a correct way. If goods have been damaged in large amounts, PS has to contact the customer and wait for their decision for what to do with the goods.

Classification: Internal error

5.5 Customer Specific Quality Deficiencies Customer A

A number of quality deficiencies were only identified for one customer. In this section, quality deficiencies that are specific for customer A are presented.

5.5.1 Labelling of Parcels at a Buffer Location

In the inbound process for the mezzanine flow some items are delivered in high volumes, meaning that they need to be stored in a pallet buffer location to not take up unnecessary space at smaller buffer locations. In this flow a parcel gets a unique location identity label. This means that if the label is put on the parcel directly, the person retrieving the parcels from the buffer needs to look through all of the parcels to find the right one, before it can be moved to a picking location. To reduce the need for searching for the parcel with the correct identity label, the employees place all the identity tags in a plastic folder which is placed on the pallet. The one retrieving the parcels from the buffer can then take any parcel and add the right identity label before moving it.

This is working well, as long as there is the same number of items in a every parcel, if there are a difference in the number of items it increases the risk for wrong inventory levels at the picking

location. To mitigate this risk, a big label is put on the pallet to make the employees aware that they need to be extra careful about choosing the right label to a specific parcel.

Classification: Prevention

5.5.2 Restocking of Return Goods

When handling returns, there may arise some problems that will affect the outbound processes. One example is that the employee handling returns may put the item on the wrong location and may thereby constitute to a picking error at a later stage. Another issue that can be derived from handling returns is that the employee does not count the products correctly at the location and the inventory levels will thereby be incorrect. This risk is mitigated by having staff from PS going to the same location and double check the inventory balance when there are discrepancies in the inventory at the location compared to the WMS. Since restocking of returned goods may cause shortage in inventory or surplus inventory, the time spent to handle this deficiency is included in those two deficiencies.

Classification: Internal error

When goods are received and entered into the WMS, sometimes there is no open picking location for the returned goods. This means that the warehouse operator needs to create a new pick location. This is performed in the WMS and takes extra time compared to if the goods would already have a picking location with goods, since then it is just to adjust the inventory balance on the location.

Classification: Non value added

5.5.3 Consolidation Goods are Not Coordinated

Consolidation is needed for this customer, since some orders are picked in the two different areas, the floor level and mezzanine. This means that the two picking orders needs to be coordinated and ready at a certain time to be able to be consolidated in an efficient way. If one order is delayed it causes the whole process to be delayed. Another issue in this process, is that parcels are put on the wrong consolidation location, which creates the need of locating the missing items.

Classification: Non value added

5.5.4 Inspection of all Orders Packed (mezzanine)

On the mezzanine, picking first takes place in boxes instead of directly into the parcels delivered to end customers as at the floor level. This is due to the items on the mezzanine are lacking volume data and therefore the WMS cannot determine which type of parcel that should be used. When a picking order has been completed, the items in the boxes are repacked into parcels and then moved to the correct pallet. During the repacking, all the items are counted to make sure that the order contains the correct quantity. If the picked quantity does not match with the quantity of the order, the order is recounted and if it is still wrong the packer contacts PS who has to go through the order to find which items are incorrect. This extra counting step does not take place on the ground level, where the items are directly picked to the parcels.

Classification: Appraisal

5.5.5 Misplacement of Incoming Goods

For the flow of goods to the mezzanine, no confirmation numbers are used and there is a lack of confirmation if the goods are actually at the right location and thereby available for picking. When an item is misplaced, the pickers, PS and the inbound staff need to communicate with each other to be able to find the misplaced goods. This activity is mostly performed by PS, and it is only when they cannot find a solution that they contact the inbound staff to make sure that they have performed their tasks in the right way.

Classification: Internal error

5.5.6 Error Checking Balance

Every morning a report is created which contains information about orders that do not have the available stock in storage to be picked. To manage this and to avoid the time-consuming trips for the pickers, PS changes the balance available or removes order lines from an order so that it may be picked. Reasons for why these errors occur may be that the goods are blocked as a consequence of making a quality control on behalf of the customer, or that there have been changes of the inventory balance.

Classification: Non value added

5.6 Customer Unique Quality Deficiencies Customer B

In this section quality deficiencies that are connected to customer B are presented.

5.6.1 System Limitation in Packaging

Even though Schenker uses many different sizes of packaging boxes to send the goods in, there are not always a suitable size available. This may sometimes lead to that the picker prepares a box for an order and then later realises that this is not the right size for the order and then either needs to be repacked or sent without an outer box. This creates unnecessary steps in the process and is caused by limitations in the WMS.

Classification: Excluded

5.6.2 Misdirection of Goods

Goods that should be stocked on floor level may be shipped to the mezzanine and therefore results in an unnecessary transportation down to the floor level. This is a consequence of not having appropriate labelling of the incoming goods and being delivered on mixed pallets with goods to both the mezzanine and the floor level. The misdirection of goods is discovered by the staff that are working in the inbound process, and the goods are then moved to another location, where the staff can input the data of the goods in the WMS.

Classification: Non value added

5.6.3 Multiple Identities on One Location

When handling inbound deliveries of the same article but registered on different rows on the delivery note, the inbound employees need to manually change the number of entities that are allowed to be stored on a single picking/buffer location. This is to avoid a situation where there is a shortage of locations as a consequence of needing to store single items on a location. When manually changing the location in WMS there is a risk of other articles being directed to the specific location, which will cause problems downstream as it is not supposed to be two articles on the same location. Even though this way of managing the inbound flow of goods takes longer time, there is an agreement with the customer that this way of handling the problem is

appropriate. What makes it a quality deficiency is the risk and time it takes to correct when something goes wrong in this activity.

Classification: Excluded-Contract

5.6.4 Articles Located on Two Different Zones in Warehouse

If the articles are located in two zones it may cause a WMS problem because the articles are reserved to certain orders. If an article is placed on two locations, it is only possible to pick from one of them. This means that when the products have been reserved to an order, someone needs to make sure that the items are transported to the right picking location. This can for example be a movement from buffer location to the picking location at mezzanine. If the goods are not moved before they should be picked, it will cause problems.

Classification: Internal error

5.6.5 The Following Line Becomes Incorrect

The following line becomes incorrect is an issue that arises as a consequence of the system having problems with larger orders. When a large order should be picked from multiple locations the picker sometimes gets an error message and needs to contact the GL or PS to solve the issue. They then forward the issue to the IT department who tries to solve the issue. In the worst case, PS needs to have direct contact with the IT support function to be able to solve it. This takes a long time, but during the contact it is possible for the picker to pick by list instead of using the scanner.

Classification: Internal error

5.7 Customer Unique Quality Deficiencies Customer C

In this section quality deficiencies that occur for customer C are presented.

5.7.1 Opened Store Pack

Many of the articles stored in the warehouse for this customer should be delivered in store packs. A store pack is an item which contains a number of smaller units and the smaller units should not be sent to end customer. This may cause a problem when it comes to the picking accuracy as the pickers misunderstand the information given to them and might not know whether they should pick a store pack or pick a single item inside the store pack. If someone opens a store pack, opened store packs are not supposed to be sent to the stores, as they are only supposed to get multiples of store packs.

If someone finds an opened store pack, they should take this package directly to PS who can manage it by either combining it to make a full store package or put it into storage that are dedicated to the e-commerce. If no one is moving the opened store packs directly to PS, it is either found when PS checks the picking locations or the ones that are moving goods from buffer to picking location finds left over articles and then moves them to PS. This also results in surplus inventory at the picking location and that the customer receives to few items.

Classification: Internal error

5.7.2 Adjust Time Loggings

In the beginning of the workday the GLs look through and adjust the time logs from the day before to make sure that everybody has been logged into the correct process as well as making sure that no one has forgotten to log in. The adjustment of the time logs is performed to ensure

that the temporary staffing agencies are paid for the services that they have provided. Another reason for this action is to get the right statistics to calculate the productivity of each process to be able to follow up the work.

The time adjustments are considered to be a deficiency since it does not add any value, but is rather a consequence of not having enough time clocks available in the warehouse to make it efficient to switch between processes. Also, people may not be paying attention and forget to change or log in when they are starting/ending their workday.

Classification: Non value added

5.7.3 Waiting for Replenishment of Pick Location

When using fixed picking locations for products it means that the locations have to be refilled from a buffer if someone picks the last items or if there is a shortage in inventory on the location. This can take some minutes and to avoid unnecessary waiting time it is possible to skip the order line and come back to the location in the end of the round. If there are many movements between buffer to pick location at the same time it can lead to the picker having to wait for the goods to be moved to the picking location.

Classification: Non value added

5.8 Summary of Identified Quality Deficiencies

A summary of all the identified quality deficiencies is presented in Table 3. For which customers a deficiency occurs, in what part of the process in the warehouse operations and which category of the CoPQ model is presented. A deficiency may have the classification of excluded, either due to contract or due to out of scope. Excluded deficiencies were not quantified.

Table 3: Summary of the identified quality deficiencies

Chapter section	Quality deficiency	Customer	Process	Category
5.2.1	Switched Labels	A,B,C	Inbound	Internal error
5.2.2	Supplier Error Inbound	A,B,C	Inbound	Appraisal
5.2.3	Height of Pallet Error	A,B,C	Inbound	Internal error
5.3.1	Picking Errors	A,B,C	Outbound	Internal error
5.3.2	Sorting Errors	A,B,C	Outbound	Internal error
5.3.3	Supplier Error Outbound	A,B,C	Outbound	Internal error
5.3.4	Surplus Inventory	A,B,C	Outbound	Non value added
5.3.5	Shortage in inventory	A,B,C	Outbound	Internal error
5.3.6	Labels Do not Print	A,B,C	Outbound	Internal error
5.3.7	Handling Claims	A,B,C	Outbound	Non value added
5.3.8	Missing Customs Documentation	A,B,C	Outbound	Internal error
5.3.9	Managing Wrong Volume Data	A,B,C	Outbound	Internal error
5.3.10	Pallet Collapse in Racking	A,B,C	Outbound	Internal error
5.3.11	Identification Problem	B,C	Outbound	Internal error
5.3.12	Picking Inspections	A,C	Outbound	Appraisal
5.3.13	Rearrange Pallet/Parcels	B,C	Outbound	Non value added
5.4.1	Education of Staff	A,B,C	Miscellaneous	Prevention
5.4.2	Transportations	A,B,C	Miscellaneous	Non value added
5.4.3	Waiting	A,B,C	Miscellaneous	Non value added
5.4.4	Warehouse Maintenance	A,B,C	Miscellaneous	Prevention
5.4.5	Damaged Goods	A,B,C	Miscellaneous	Internal error

5.5.1	Labelling of Parcels at a Buffer Location	A	Outbound	Prevention
5.5.2	Restocking of Returned Goods	A	Inbound	Internal error/non value added
5.5.3	Consolidation Goods are Not Coordinated	A	Outbound	Non value added
5.5.4	Inspection of all Orders Packed (mezzanine)	A	Outbound	Appraisal
5.5.5	Misplacement of Incoming Goods	A	Inbound	Internal error
5.5.6	Error Checking Balance	A	Outbound	Non value added
5.6.1	System Limitation in Packaging	B	Outbound	Excluded
5.6.2	Misdirection of Goods	B	Inbound	Non value added
5.6.3	Multiple Identities on One Location	B	Inbound	Excluded
5.6.4	Articles Located on Two Different Zones in Warehouse	B	Outbound	Internal error
5.6.5	The Following Line Becomes Incorrect	B	Outbound	Internal error
5.7.1	Opened Store Pack	C	Outbound	Internal error
5.7.2	Adjust Time Loggings	C	Outbound	Non value added
5.7.3	Waiting for Replenishment of Pick Location	C	Outbound	Non value added

6. Time-consumption of Managing Identified Quality Deficiencies

In this chapter the results of the quantification of the identified quality deficiencies from the previous chapter are presented, answering the second research question of the thesis, "*How much time is spent on managing quality deficiencies?".* Since there are many different types of quality deficiencies occurring for the different customers it is important to focus on the ones that have the largest impact on the operations. Therefore, the quality deficiencies with the largest impact, for each of the customers, were considered to be the most significant and were therefore the focus for research question three, which will be studied in chapter 7.

Quality deficiencies that were not quantified are presented in 6.1. Estimations had to be made to be able to quantify the time spent on transportation and waiting and these estimations are presented in section 6.2. This is followed by a presentation of the result of the quantification for each customer. The data is first presented according to the adapted version of cost of poor quality (CoPQ) model (section 3.7.1) showing the distribution between the four categories, and then each category is explained in more detail by showing which deficiencies in each category that are contributing the most to the time spent. When each category is explained, the time spent is shown as hours spent on an activity per day. The final section is summarizing the quantification and presenting which deficiencies would be the most relevant to improve for each customer.

6.1 Not Quantified Quality Deficiencies

Some of the identified quality deficiencies in chapter 5, are not a part of this quantification chapter. There are three reasons, firstly deficiencies that are excluded by contract, secondly it was not possible to measure some of the deficiencies, and lastly some deficiencies did not occur during the data collection period. A summary of which deficiencies that are not included can be seen below in Table 4.

Table 4: Excluded or not measurable quality deficiencies during the data collection period

Chapter Section	Quality deficiency	Chapter Section	Quality deficiency
5.3.3	Supplier Error Outbound	5.6.1	System Limitation in Packaging
5.3.8	Missing Customs Documentation	5.6.2	Misdirection of Goods
5.3.13	Rearrange Pallet/Parcels	5.6.3	Multiple Identities on One Location
5.5.3	Consolidation Goods are Not Coordinated	5.7.3	Waiting for Replenishment of Pick Location

The inbound process was not included in the survey data collection since most of the deficiencies that happen in this process are not detected until the outbound process. The time required to solve the problems caused by inbound could be collected from the employees working at production support (PS).

6.2 Estimation of Transportation and Waiting

Most of the quality deficiencies require the warehouse operators to contact (PS) to get assistance. These deficiencies require transportation to be able to get in contact with PS and it may also involve waiting for PS to solve the issue before the operator can continue. The estimations for the distance, speed and waiting time is explained in this section. The estimations are based on the same logic for all customer cases.

6.2.1 Transportation to PS

When a picker has to contact PS to get help with an issue, the picker has to travel to PS workstation. To calculate the time needed to make the trip to PS, the distance between the location where the problem occurs and PS was estimated. It is assumed that on average the picker is half the total length of the section of the warehouse dedicated to the customer plus half the total depth of the racking sections away from PS. For the deficiency shortage in inventory, the picker has to travel to PS and then to a new location before the picker can continue their picking route. This means that it is likely that the picker has to move more than two times the distance as the new location may not be in the existing route and 20 % is added due to this. Therefore, a factor of 2.2 is used to calculate the total distance that a picker needs to move to be able to get help from PS, get to the new location and then back on the picking route. When it comes to the quality deficiency surplus inventory the distance is set to the factor 1.0 instead, since surplus inventory is more frequently found in the route of the warehouse operator's existing tasks and therefore does not add as much extra distance.

The full speed of a forklift is 3 m/s but it is assumed that it is not possible to go at full speed when a picker goes to PS. For a picker driving a forklift at floor level, the speed is assumed to be 1.3 m/s since the picker might have to slow down and accelerate due to other forklifts and turning around corners. The decision to calculate with 1.3 m/s comes from internal documents at Schenker as well as driving a specified distance and measuring the time it took to travel. The speed of a picker walking with a trolley on the mezzanine was based on internal documents and by following a picker a known distance and also testing to perform the same tasks. This resulted in an estimation of travelling speed of 1 m/s. The distance was then divided by the speed and the result is how much time an operator spends on transportation per problem, for both mezzanine and floor level. This was then multiplied with the total number of problems that require assistance from PS to get the total amount of time spent on transportation for each customer.

The plausibility of these estimations was validated in two ways, a simple time study and asking a supervisor whether the estimations were reasonable. Since both the time study and the supervisor confirmed the estimations, they were considered to be sufficiently reliable for their intended use.

6.2.2 Waiting for PS to Handle Quality Deficiencies

Some problems that a picker encounters requires PS to solve it immediately. During the time it takes for PS to solve the problem, the picker has to wait. It was assumed that a picker does not have to wait in line to get help from PS and that PS is always available for supporting the warehouse operations, as it is a dedicated function as well as they are prioritizing to help pickers. The time that the warehouse operator has to wait until a problem is resolved is estimated to be the same time it takes for PS to solve the issue.

PS was asked about which problems require a warehouse operator to wait for while PS solves the issue and if the estimation that time to solve the issue was approximately the same as the waiting time.

6.3 Customer A

In this section the results from the quantification of the quality deficiencies that occur in the operations for customer A are presented. The data were collected during a ten work days between 2019-02-18 and 2019-03-01.

6.3.1 Aggregated Data Presentation

The time spent on quality deficiencies that were collected for customer A comes from five different sources which are based on survey results and estimations. These are the time that PS spends on handling quality deficiencies, the time pickers need to move to PS to get help, education of staff, waiting time for pickers and the time that is spent on appraising the quality of the picking accuracy at mezzanine. The time spent on each of these categories is presented below in Table 5. The total sum of time spent on handling quality deficiencies were then compared with the total number of hours spent on the inbound and outbound processes, which were 289 hours/day.

Table 5: Data sources for time spent on quality deficiencies for customer A

Description	**Hours/day**	**% of total hours**
PS work with quality deficiencies	22.4	7.7%
Pickers travel to PS	3.5	1.2%
Pickers waiting at PS	1.1	0.4%
Appraisal of picking quality	2.3	0.8%
Education	6.9	2.4%
Total time spent	**36.1**	**12.5%**

In the data collected through the survey from PS, there were a few missing hours, that is hours that were not accounted for in the survey. About 12 % of the time was not accounted for by PS compared to how many hours they were working, and this missing time includes time spent on activities which were not part of the survey such as bathroom breaks, breakfast, responding to emails, answering questions etcetera. Since most of the workday for PS was accounted for with only a relatively small portion of the time missing, the data was considered to be reliable in this regard. These five sources of data were then compiled into the four categories of the adjusted version of Harrington's model in subsection 3.7.1 and summarised in Figure 12 below.

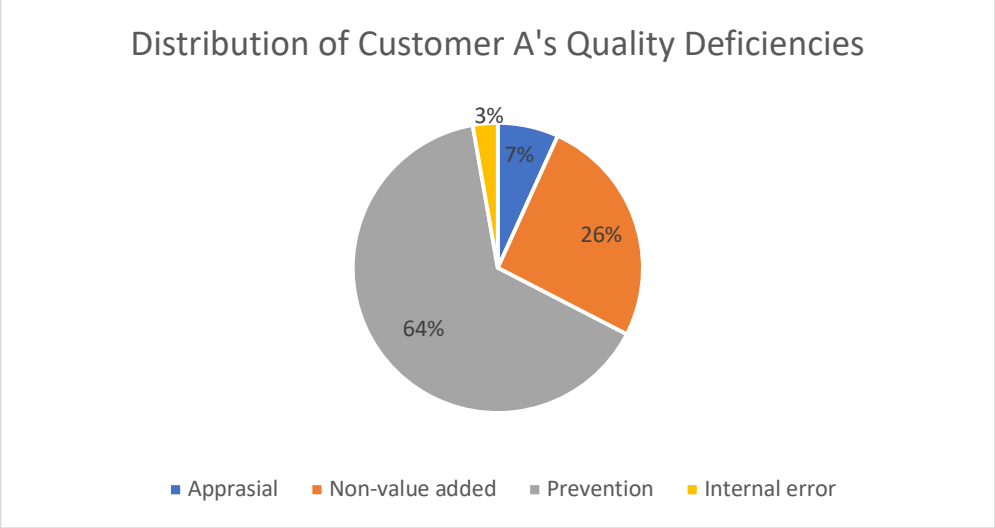

Figure 12: Time spent on quality deficiencies for customer A, divided into the four classifications of CoPQ

As can be seen in the figure, the majority of the time spent on quality deficiencies is due to prevention activities, followed by non value added and appraisal. Only a small part is spent on internal errors and therefore the focus in the following subsections is on breaking down the data

for the two biggest groups. The data presented in the following figures are showing the hours spent on average per day as a result of the deficiencies.

6.3.2 Prevention

There are two main prevention activities, which is education of staff in the operations and the second one is warehouse maintenance which is performed by PS both at floor and mezzanine. In Figure 13 below, the distribution of the time spent on the different prevention activities are shown. The warehouse maintenance is separated into two categories.

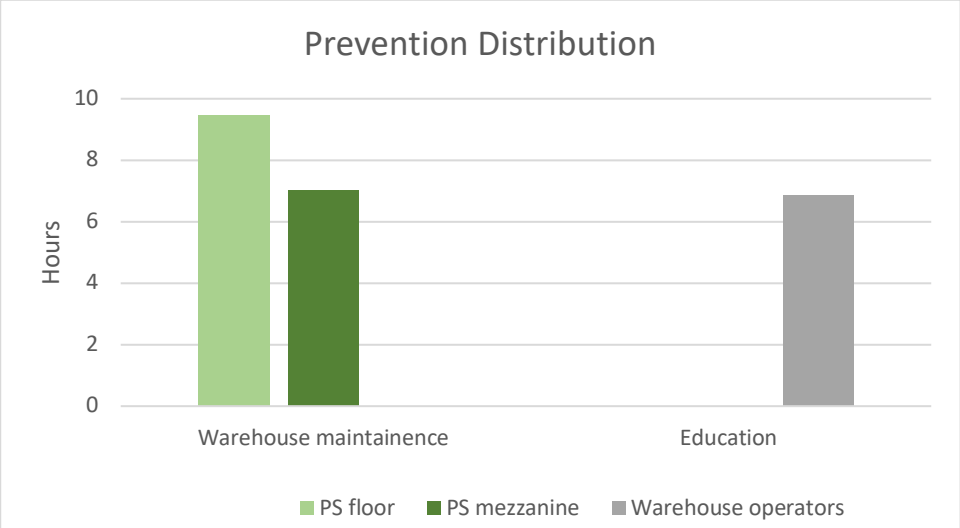

Figure 13: Distribution of the time spent on prevention activities

Warehouse maintenance is the single most time-consuming quality deficiency for this customer case. Moving goods between different locations in the warehouse takes a lot of time and does not add any value directly to the customer. This quality deficiency is affected by the customer to a large extent due to the balance of the flow of inbound and outbound goods. If the customer is having a greater inbound flow than the outbound flow during a short period of time, it means that the warehouse locations will be filled and thereby increase the need for warehouse maintenance.

In this customer case, it is partly due to the contract that a lot of time has to be spent on warehouse maintenance. There are no capacity limits written in the contract and it is also not stated in what batch sizes the goods should be delivered and stored at the warehouse. These two factors increase the time that is needed for warehouse maintenance as it impacts the storage space utilisation.

The last category concerns the hours spent on educating both new staff as well as broadening the competences of current employees. Education was around 2.5 % of the total hours that are spent on this customer during the time for the data collection. As mentioned before, new staff is frequently appearing in this type of business and therefore the education percentage during the data collection was compared to the time spent on education during 2018, which was 6.1 %. This indicates that the time period of the data collection is not representative for a whole year but to compare the time spent on education with the other data collected it was still used. With the current business practice of using temporary staff, education of new employees is needed more frequently as they are more likely to move between workplaces.

The time spent on education and warehouse maintenance will be compared and presented chapter 7 to see whether there are any differences and analyse why if there are considerable differences.

6.3.3 Non Value Added

The distribution of the non value added activities are shown in Figure 14. The green bars show activities performed by PS while the grey bars show the non value added activities that are due to the warehouse operators. The time that is spent by the warehouse operators is mainly due to transportation to PS.

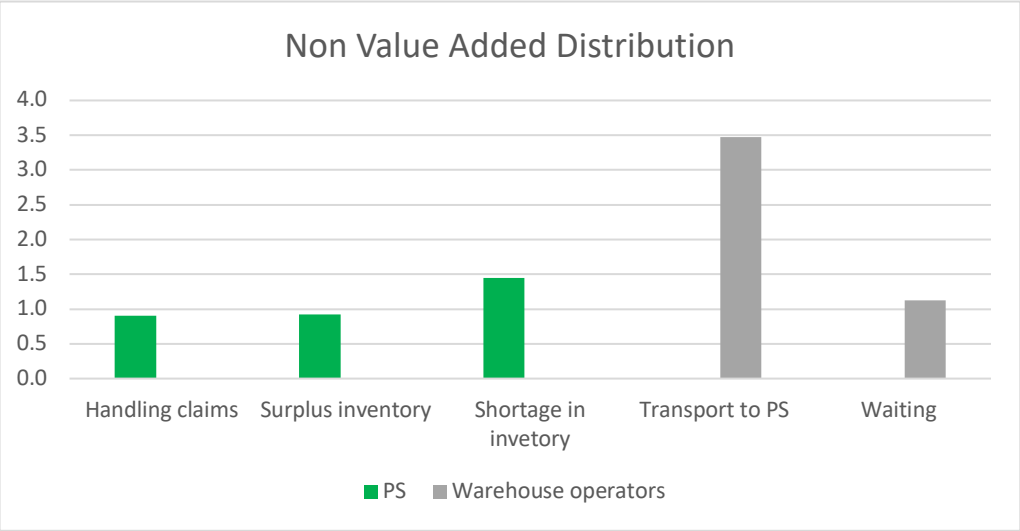

Figure 14: Distribution of the time spent on non value added activities

The main reason for these transports is the occurrence of shortage in inventory at floor level, which also is the main part that PS spend time on in this category. A possible reason for why shortage in inventory occurs more frequently, in absolute numbers, on the floor level is twofold. Firstly, there are bigger volumes picked and thereby the number of picking error is expected to be higher than on the mezzanine, thereby resulting in picking locations with wrong inventory balance. Secondly, there is no activity in place to ensure that picking errors are detected before a completed order is shipped as there is on the mezzanine.

How the time for transports and waiting can be reduced is studied in chapter 7.

6.3.4 Appraisal and Internal Errors

The two categories that are left are appraisal and internal errors. Together the two categories add up to 3.8 hours per day. The time spent on appraisal is due to inspecting goods which have a reported supplier error and counting all orders on mezzanine which takes the most time, about 2.3 hours per day. Internal error consists of many quality deficiencies, which can be found in section 5.8 and about 1.3 hours are spent on managing all the different internal errors per day.

The value of the appraising activity in terms of time is investigated in section 7.5 by comparing the time spent on appraising the number of items picked and the time spent on managing picking errors. The internal errors for customer A will not be further studied since they account for a small portion of the time spent on handling quality deficiencies.

6.3.5 Summary

The following deficiencies were considered to be the most important:

- Warehouse maintenance 9.5 hours
- Education 6.9 hours
- Transportation 3.5 hours
- Appraisal on mezzanine 2.3 hours

These quality deficiencies from customer A will be investigated further in chapter 7.

6.4 Customer B

In this section the results from the quantification of the quality deficiencies that occur in the operations for customer B are presented. The data were collected during ten working days between 2019-03-01 and 2019-03-18.

6.4.1 Aggregated Data Presentation

Four data sources were used for customer B consisting of time PS spends on quality deficiencies, transportation, waiting and education. No appraisal activities are performed regularly for customer B and no time was spent on appraisal during the data collection period. The collected data were compared with the total hours spent on this customer which were on average 190 hours per day. Table 6 shows the data sources used.

Table 6: Data sources for time spent on quality deficiencies for customer B

Description	**Hours/day**	**% of total hours**
PS work with quality deficiencies	6.3	3.3%
Pickers travel to PS	1.2	0.6%
Pickers waiting at PS	0.2	0.1%
Education	4.4	2.3%
Total time spent	**12.0**	**6.3%**

A big difference comparing the tables between customer A and customer B (Table 5 and Table 6) is the time PS spends on handling quality deficiencies. It is important to note that Customer B has one employee working as PS compared with four to six for customer A. The data was then divided into the three categories of CoPQ. This is shown in Figure 15.

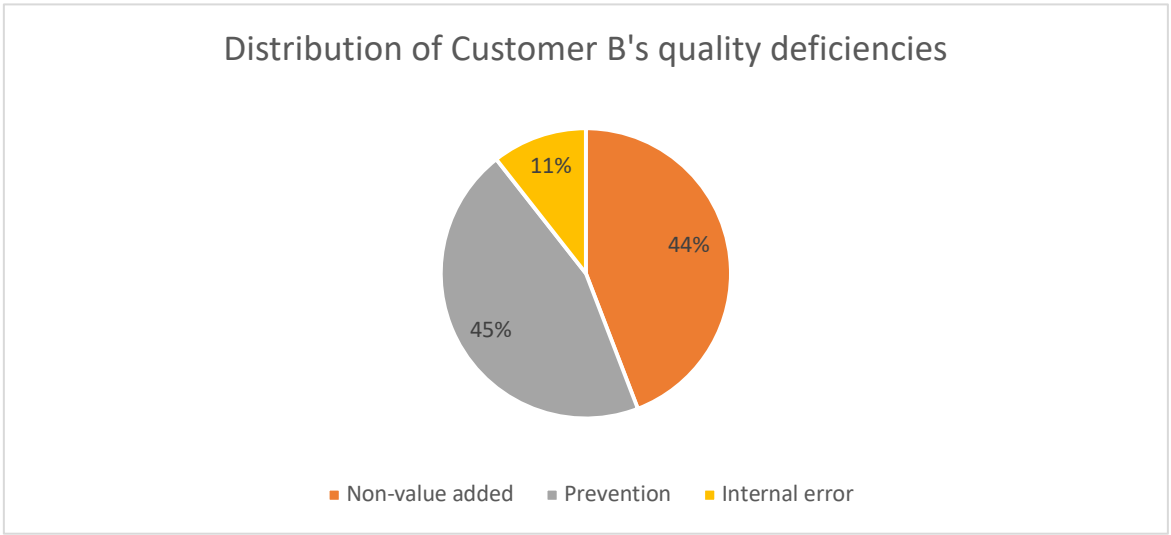

Figure 15: Time spent on quality deficiencies for customer B, divided into three classifications of CoPQ

Once again most of the time is spent on prevention activities, with the classification non value added following closely behind. Internal error accounts for a larger share for this customer compared with customer A. The missing hours in the data collection from PS were 10 % which is about the same as for customer A and the data was considered to be reliable with the same reasoning. The categories of CoPQ are divided into their components in the following sections.

6.4.2 Prevention

The main prevention activities are warehouse maintenance and education of staff as seen in Figure 16 below.

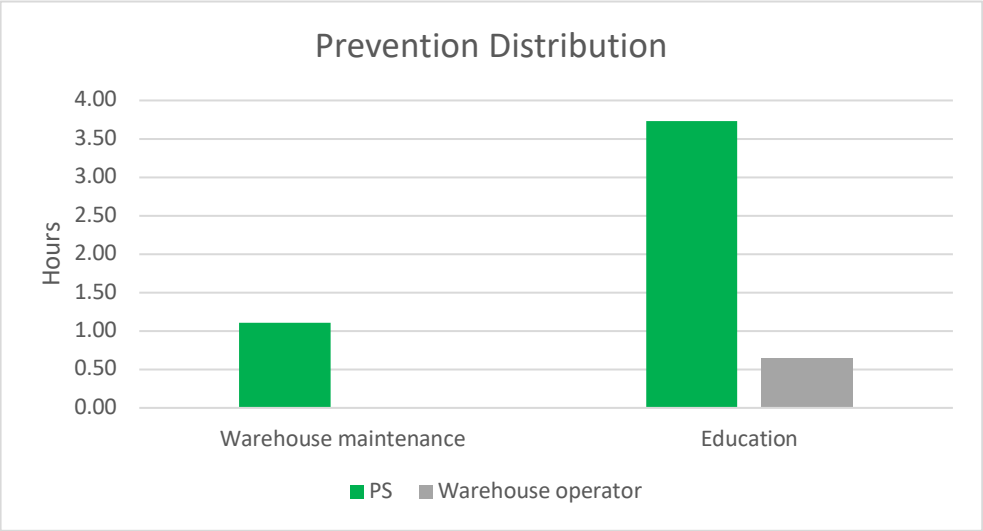

Figure 16: Prevention hours distribution for customer B

Warehouse maintenance is an activity which is time-consuming for this customer as well but not on the same level as for customer A, because of the difference in material flow for the customers. For customer B there are currently enough locations available to have an efficient inbound process without having to perform constant warehouse maintenance.

During the data collection, one employee was trained to learn the activities performed by PS which is why many hours were spent on education for PS. Comparing the education which took place during the data collection period with the yearly education hours for 2018, the education was higher than the yearly average for the data collection period. During the time period 2.3 % of the time was spent on education, compared to the yearly (2018) average of 1.1 % of the total time spent on the inbound/outbound processes.

6.4.3 Non Value Added

The non value added category consists of the same activities as for customer A as can be seen in Figure 17. The largest portion of the non value added activities are performed by PS, which is about three quarters of the time.

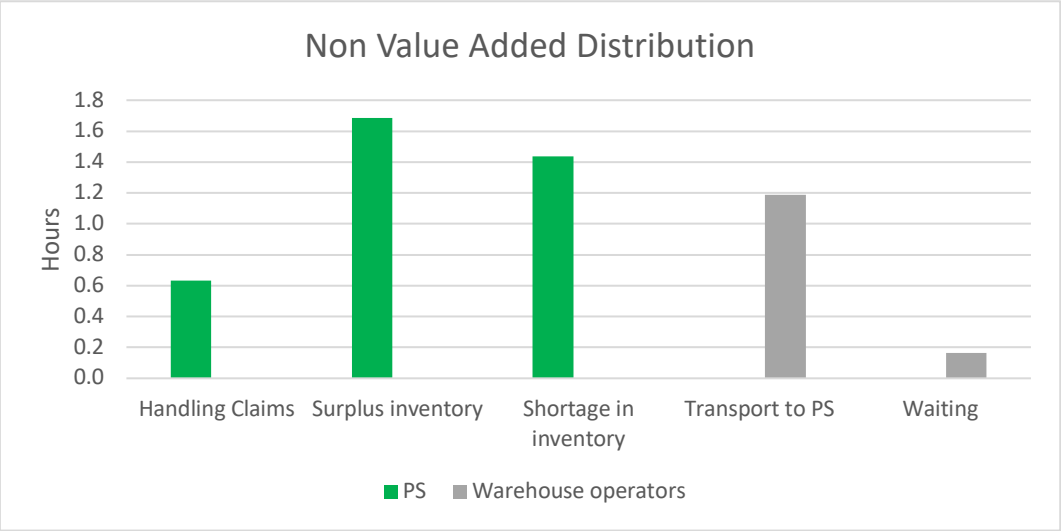

Figure 17: Distribution of the time spent on non value added activities for customer B

Surplus inventory and shortage in inventory are the activities which PS spends the most time on managing, including internal error activities as well. Most of the problems with inventory balance occur at mezzanine because it is easier to make mistakes since smaller items are stored at mezzanine and the items are placed close to each other. When either surplus inventory or shortage in inventory occur, PS has to check the inventory of that item which takes time. Comparing this with the set up for customer A, PS for customer B controls all the picking locations of this item and not only the location that had shortage in inventory.

Transportation to PS accounts for more than one hour per day for this customer case and shortage in inventory is the main reason for the pickers to seek out PS. Not many activities require the operator to wait while PS solves the issue and if the operator has to wait then PS can usually solve it within one minute or less. Transportation is studied further in chapter 7.

6.4.4 Internal Errors

The time spent on internal errors was 11 % and thus the distribution of the time spent on different quality deficiencies was of interest which can be seen in Figure 18 below.

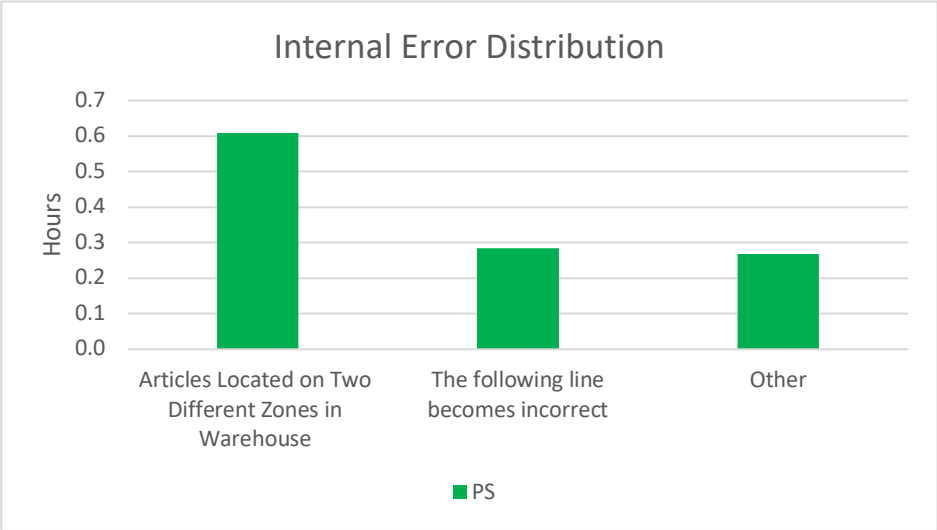

Figure 18: Distribution of time spent on managing internal errors

Articles located on two different zones in the warehouse and the following line becomes incorrect are the main internal errors. About one hour is spent on managing these errors every day. Quality deficiencies which take less than ten minutes to solve on average per day are included in the category "other". Since the individual deficiencies in the category "other" is a tiny part of the time spent on quality deficiencies, these will not be investigated further.

The following line becomes incorrect is a problem related to the warehouse management system (WMS) and is currently being investigated by the IT department. The deficiency has been improved a lot before the data collection period and is still being improved. Since the time that PS needs to spend on managing this issue is reducing and it is already not a time-consuming activity, this deficiency will not be further studied.

Articles located on two different zones, will not be studied further since PS mentioned that it has been decreasing since they started working on the issue and it is currently improving.

6.4.5 Summary

The following deficiencies were considered to be the most important:

- Warehouse maintenance 1.1 hours.
- Education 4.4 hours
- Transportation 1,2 hours

These deficiencies from customer B will be investigated further in chapter 7.

6.5 Customer C

The results of the quantification of the quality deficiencies at customer C are presented in this section. The data were collected during ten working days between 2019-03-08 to 2019-03-21.

6.5.1 Aggregated Data Presentation

For this customer case, data about quality deficiencies were collected from six different sources. The main difference compared with the other two cases was that the group leaders (GL) at outbound were considered to be involved in managing quality deficiencies to a larger extent for this customer and GL were therefore included in the survey data collection. Table 7 shows where the data have been collected from and how much time that each of the sources accounts for daily compared to the total hours spent on the customer.

Table 7: Data sources for time spent on quality deficiencies for customer C

Description	Hours/day	% of total hours
PS work with quality deficiencies	3.0	1.0%
GL work with quality deficiencies	1.3	0.4%
Pickers travel to PS or GL	0.7	0.2%
Pickers waiting at PS or GL	0.7	0.2%
Appraisal of picking accuracy	1.6	0.5%
Education	10.4	3.2%
Total time spent	**17.7**	**5.5%**

As can be seen in table, the time GL works with quality deficiencies is not a substantial amount since these deficiencies mostly just requires working with the WMS. Most of the deficiencies that GL handles require the order pickers to come to GL for assistance and therefore it was important to include to get a more accurate assessment of how much time is spent on transportation. The total hours spent per day on this customer during the data collection period was about 320 hours. There is only one employee working as PS for this customer case. The collected data are presented according to the categories of CoPQ in Figure 19.

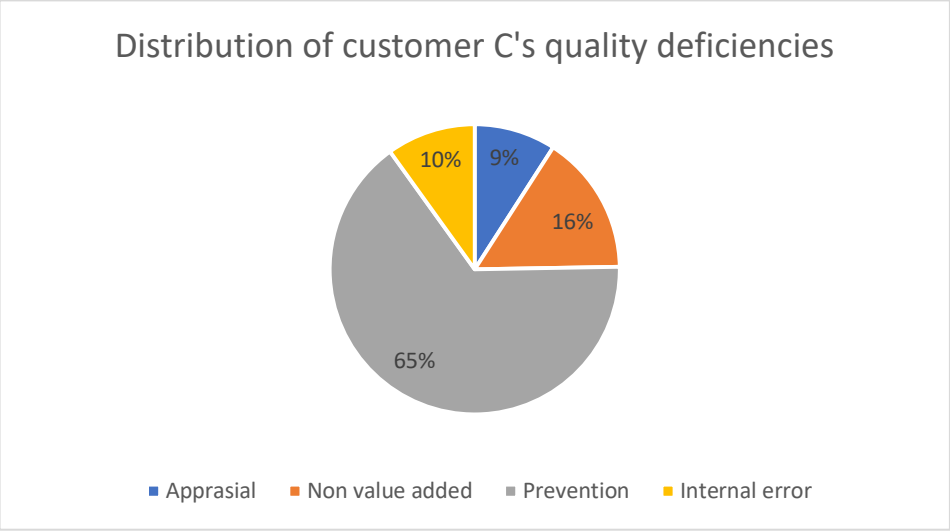

Figure 19: Time spent on quality deficiencies for customer C, divided into the four classifications of CoPQ.

The majority of the time is spent on prevention and non value added activities for this customer case as well. Missing hours were investigated for PS but not for GL since GL are mostly responsible for activities which are not related to quality deficiencies. For PS, the missing hours were 14 % of the time that was logged in the survey. After communication with PS it was realised that the missing hours include a morning break and morning meeting which had not been captured in the survey. These two together accounts for about 6.5 % of a workday. The remaining missing hours were said to come from being disturbed and managing smaller issues, which were difficult to fill out in the survey format as well as the mentioned reasons for customer A and B. This meant that the actual missing hours were considered to be acceptable for the thesis.

6.5.2 Prevention

Warehouse maintenance and education are the two prevention activities for this customer case as well. It was not possible to compare the time spent on education during the data collection period with education during 2018 since it has not been logged as its own category before. The education time for this customer is divided between further developing existing warehouse operators and educating new employees. This division was made because the education is measured this way for this customer and shows that education is measured differently between the customer cases. The supervisor estimated that the time that was spent on education of new staff was higher during the data collection period compared to an average period. Figure 20 shows the time spent on education and warehouse maintenance for this customer case.

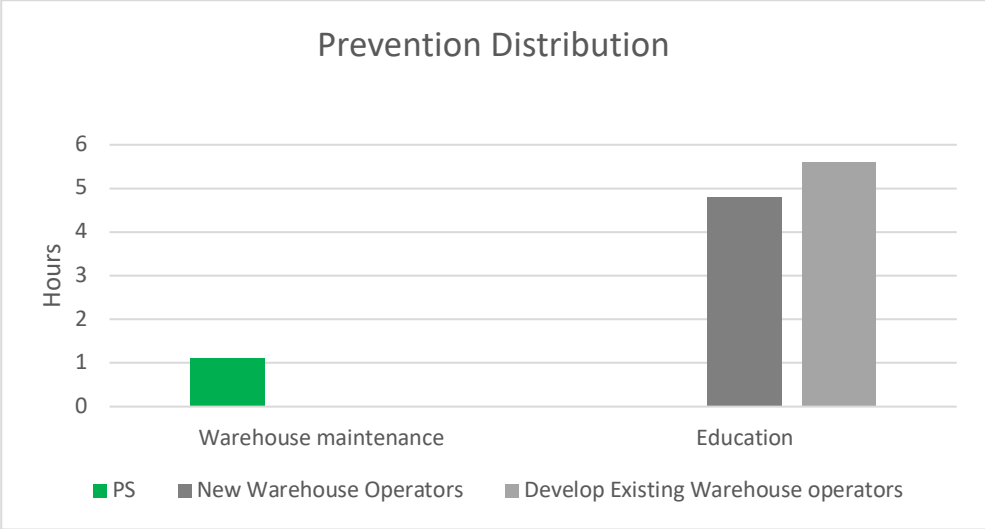

Figure 20: Prevention hours distribution for customer C.

About 1.1 hours are spent on warehouse maintenance every day by PS. Fixed stock locations are used for this customer and this means that pallets do not have to be moved around to different locations in the warehouse as much compared with a class-based storage assignment used for the other customer cases. Less time is therefore spent on warehouse maintenance due to the stocking assignment.

Education and warehouse maintenance will be a part of chapter 7 as comparison between the customer cases.

6.5.3 Non Value Added

The non value added activities are shown in Figure 21 below. Waiting and transportation to PS or GL are the activities which account for the largest part of this category with the remaining activities together adding up to approximately the same amount of time.

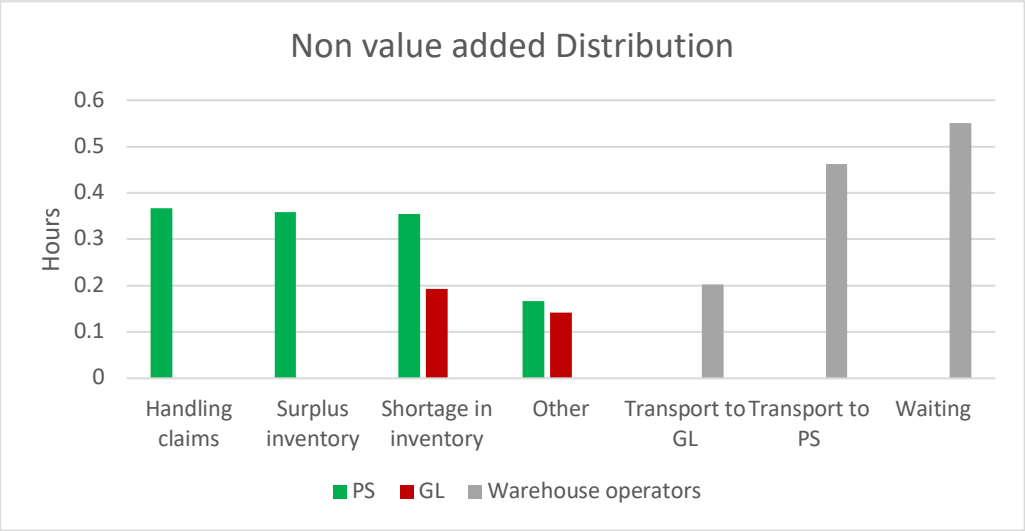

Figure 21: Distribution of time spent on non value added activities for customer C

Handling claims from end customers is not a time-consuming activity for customer C. As was explained in the customer case chapter (subsection 4.5.3), the customer and end customer are the same since the customer has their own stores. This means that if wrong quantity or wrong items are shipped to the end customers, most of the time they will not file a claim. Instead the customer will just update their inventory balance and make a new order for the missing items. However, in the e-commerce flow, the customers do file claims if they receive the wrong items.

Shortage in inventory is managed both by GL and PS. GL mostly just search for information about available stock in the WMS while PS sometimes also go to the picking location with shortage in inventory to check the inventory levels. In the category "Other", non value added activities which each account for less than ten minutes per day are included and these are not further investigated.

Transportation and waiting are the most time-consuming activities in the non value added category, which take 0.7 hours and 0.6 hours respectively. The same deficiencies as for the two other customers require the pickers to go to PS or GL, that is mostly shortage in inventory and some of the internal errors. A fixed storage assignment is used for this customer, and this may reduce the number of times a picker has to contact PS or GL. If a picker is supposed to pick from a location with no inventory the picker can send a replenishment request. The picker can then skip the location and come back to it later, which means that there is a chance that the location has been replenished and there is stock available to pick again. This means that the picker does not need to contact PS or GL as often compared with the other customers cases. If there is no inventory in stock, then picker can skip the location all together. Transportation will be investigated further in chapter 7 for this customer case as well.

6.5.4 Appraisal and Internal Errors

The distribution of the time spent on internal errors are shown in Figure 22 below. As can be seen in the figure, most of the time is spent on handling internal errors are by GL.

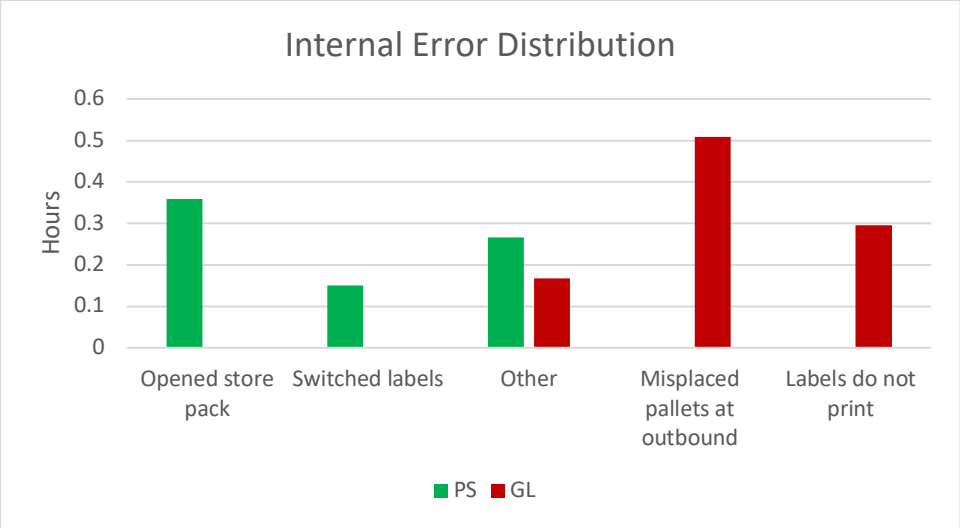

Figure 22: Distribution of time spent on managing internal errors for customer C

Opened store pack and switched labels are what PS spends most of their time on in the classification internal errors. These two require the pickers to move to PS. The category "Other" internal errors are errors which take less than ten minutes per day to handle and are not part of chapter 7. Misplaced pallets at outbound is the quality deficiency that GL spends most time managing. Customer C has a large number of departures every day and it is easy to mix-up where to place picked pallet. Another issue is that some drivers pick up pallets from the wrong area which causes problems and GL has to find out where the pallets have gone. However, there is a solution for this deficiency which may be implemented in the near future and therefore this deficiency is not investigated further.

Appraisal is not included in Figure 22 but accounts for 1.6 hours per day. This appraisal activity is to show that Schenker reaches the goal regarding picking accuracy since the customer does not inspect the goods on arrival.

6.5.5 Summary

Summarising the most important results from the quantification of the quality deficiencies of customer C, there are three deficiencies that will be further investigated in chapter 7.

- Warehouse maintenance 1.1 hours
- Transportation 0.66 hours
- Education 10.4 hours

7 Analysis of Differences and Potential Improvements.

In this chapter the areas which were considered to be important to analyse more in depth from chapter 6 are studied with the aim of answering the third research question: *How can the time spent on quality deficiencies be reduced?* This is performed by analysing the data relevant to each section, followed by potential improvements. One of the main reasons for many of the deficiencies is the occurrence of picking errors. Therefore, this chapter is started by analysing picking errors in more detail. This is followed by an analysis of transportations and waiting, education and warehouse maintenance. Finally, important deficiencies that are specific for single customers are analysed. These are appraisal for customer A and damaged goods for customer C.

7.1 Picking Errors

Picking accuracy is a central measurement for determining the performance of the pickers and it is also used by the customer to evaluate Schenker´s performance. The picking accuracy is calculated by dividing the number of correct order lines by the total order lines picked for a period of time. Even though it is useful to measure picking accuracy it does not say anything about the time that is spent on managing the consequences of picking errors and therefore this is analysed in this section.

Reasons behind picking errors are presented first in this section, followed by the time it takes to manage the consequences of picking errors. This is then followed by a subsection about the data reliability of the statistics about picking errors and thereafter possible improvements are discussed.

7.1.1 Reasons for Picking Errors

Even though scanners are used to confirm that the right articles are picked for the majority of the flow, picking errors still occur in all customer cases. There are many things that can lead to a picking error for the different customers and the identified reasons from observations and interviews (see subsection 5.3.1) for picking errors are presented in Figure 23.

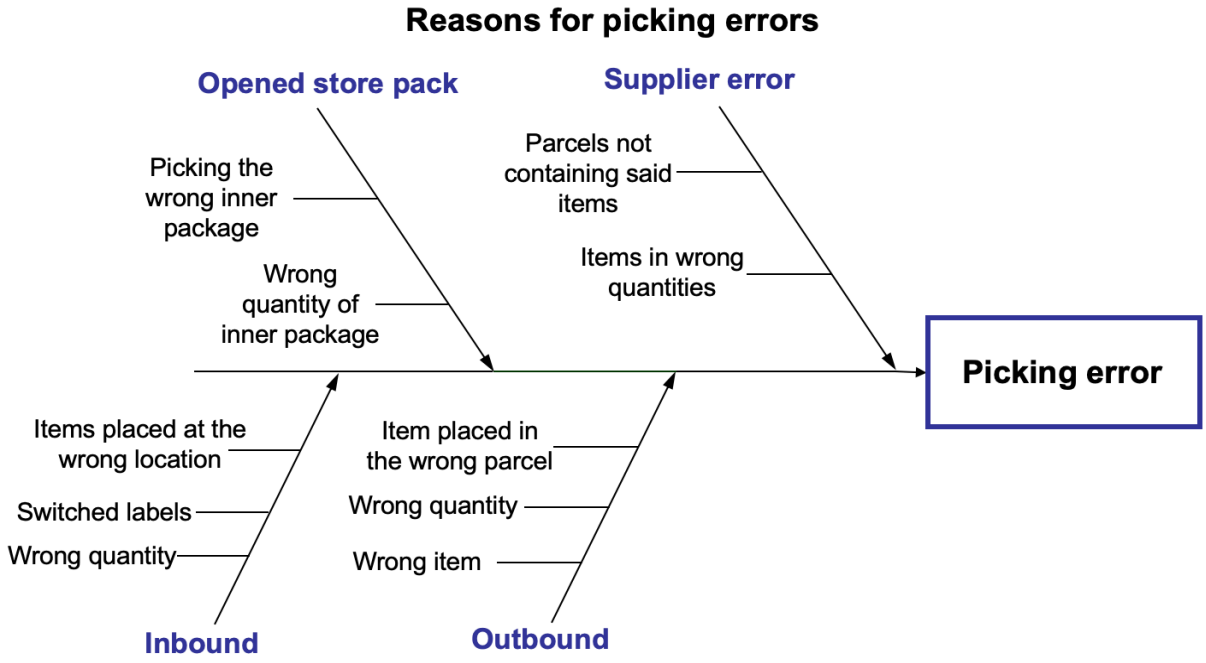

Figure 23: Possible reasons for the occurrence of picking errors.

Some reasons for picking errors are partly outside of Schenker's control as they may be the result of supplier errors. Even though these are not included in what is accepted as a claim, the consequences of these errors may still require time to manage as they may lead to both surplus and shortage in inventory.

As can be seen in Figure 23 there are many reasons behind picking errors and this variety of reasons makes it hard to determine what the root cause is for a detected picking error. This is especially true since it can take days before a picking error is detected.

Another aspect which makes it even more difficult is that picking errors may cancel each other out in terms of inventory balance and thereby it seems like no mistakes have been made in the system. For example, one order may not have received one item, but before it has been claimed another order has received one too many items. This means that the inventory balance on the picking location is correct even though in reality there has been two picking errors on the same location.

7.1.2 Time-consumption due to Picking Errors

As mentioned in the previous subsection, it may be difficult to determine the reason for a picking error, instead it is the consequences of picking errors that become visible. There are consequences that can be directly connected to a picking error while for others it is more difficult to see. For example, handling claims and returns has a direct connection to a picking error while risk of losing a customer may be a more long-term consequence of low picking accuracy. A presentation of possible consequences can be seen in Figure 24.

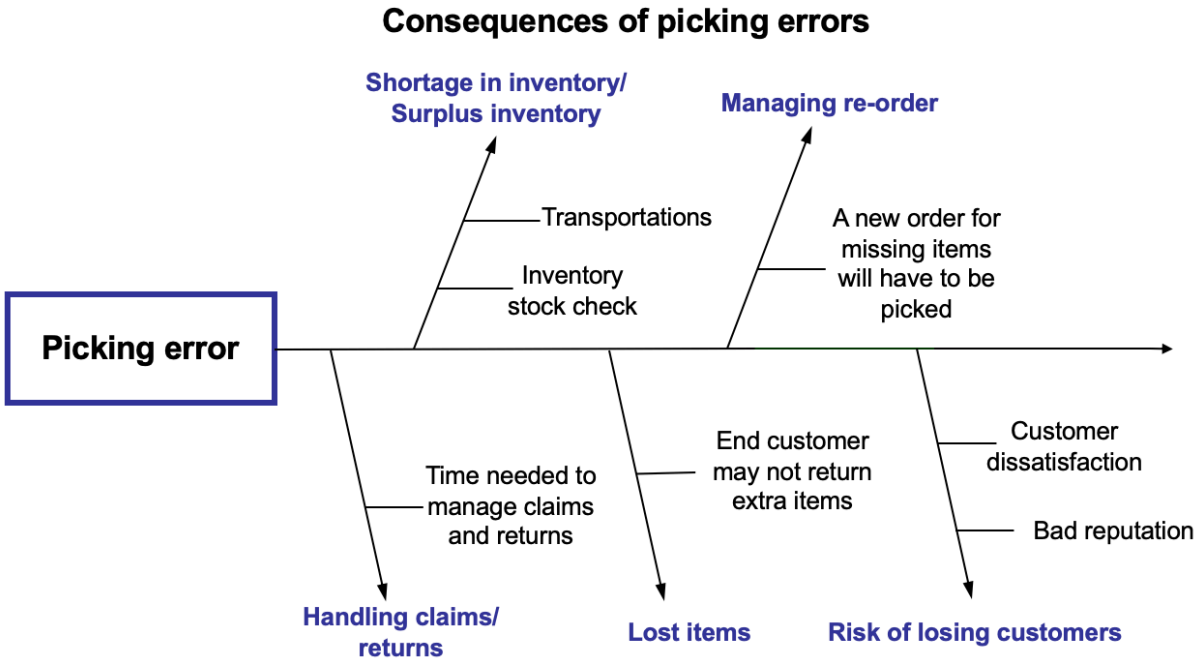

Figure 24: Consequences that may be the result of a picking error

In Table 8, an analysis has been performed which assumes that all shortage in inventory or surplus inventory are a consequence of picking errors. This shows that customer A spends the most time of the three customer cases when it comes to managing the impacts of picking errors. From the table it is also possible to see that the actual time that is spent on managing claims is quite small compared to the total hours spent on managing the consequences of picking errors.

Instead it is transportation and managing shortage/surplus inventory that are the most time-consuming activities.

Table 8: Statistics regarding picking errors.

Activities taking time	**Customer A**	**Customer B**	**Customer C**
Transportation (h)	3.2	1.0	0.5
Manage surplus goods (h)	0.9	1.7	0.4
Manage shortage in inventory (h)	1.0	1.4	0.4
Handle claims (h)	0.7	0.6	0.4
Waiting (h)	0.4	0.1	0.4
Manage reorders (h)	0.1	0.1	-
Sum (h)	**6.3**	**4.9**	**2.0**
Hours spent in total (h)	289	190	320
Order lines picked	6 930	3 306	5 105

The activity of managing a re-order needs to take place when a customer has not received the right item or the right amount, and therefore a new order needs to be picked. The time that it takes to manage a re-order is estimated by taking the total number of picked lines divided by the hours spent on outbound, which is the productivity of the outbound process. Then the total accepted claims lines per day is divided by the productivity to get how many hours are needed to pick the re-orders. For customer C, this reasoning is not applicable as they are not having a direct correlation between picking hours and claims, as they own their own stores.

The impact of having picking errors should also consider the value of the items that are lost as not all customer may send back items if they have received too many as well as the need for extra transportation and customer dissatisfaction.

7.1.3 Hidden Statistics Regrading Claims

Studying the claims statistics, it is possible to calculate the picking accuracy for the different customer cases. The picking accuracy during the periods for the data collection is presented in Table 9 below, and the number of claims is shown as a daily average. The picking accuracy for customer C is not calculated using claims and picked order lines, instead it is based on an appraisal activity performed. Customer C has lower picking accuracy and this is reasoned to be a consequence of the end customers not inspecting their goods on receival and thereby the incentives for Schenker to reach a higher picking accuracy is expected to be lower. Since the pickers are measured only on how fast they are picking for the most part, the quality of the picking, that is the picking accuracy might be negatively affected, since the picker seeks to maximise their picking speed.

Table 9: Statistics regarding claims

	Customer A	Customer B	Customer C
Picking accuracy	99.93 %	99.95 %	99.36 %
Accepted claims	4.7 lines	1.5 lines	-
Accepted, picked too many	0.6 lines	0.1lines	-
Accepted, picked too few	2.2 lines	1.0 lines	-
Accepted, other reasons	1.9 lines	0.4 lines	-
Total claims (accepted + rejected)	8.3 lines	3.7 lines	-
Picked order lines	6 560	3 032	5 531
Wrong inventory balances occurrences			
Shortage	66	16.7	8
Surplus	23.8	14	3.5

Comparing the number of order lines that are claimed for being over- or under-delivered in quantity shows that shortages are claimed to a much larger extent. If it is assumed that picking too many and too few are equally likely to occur, then it can be concluded that it is more likely for the end customer to make a claim when there is a shortage than if they have received too many items.

This is supported by data regarding the frequency of shortage in inventory versus surplus inventory. The collected data shows that shortages occur with higher frequency than surplus inventory, which indicates that picking errors of too many items may not be claimed to the same degree by the end customer. If all picking errors are claimed by the end customer, it should mean that there would have been higher frequency of surplus inventory as a consequence of picking too few items.

Another data source that will be discussed in section 7.5. shows that on the mezzanine for customer A the picking errors detected in the appraisal activity show that picking too many accounts for 70 % of detected errors. The data regarding frequency of surplus versus shortage in inventory and the appraisal activity indicates that there are picking errors which are not collected in the claims statistics as it seems like pickers are more prone to picking too many than too few. This may indicate that the number picking errors is higher than what is shown in the claims statistics and the true picking accuracy may therefore be lower.

In conclusion, it is important to make all types of picking errors visible. If not all picking errors are visible it is more difficult to make the right decision regarding changes or improvements of a process since the problem with picking errors may seem less severe than it actually is which might lead to focusing on the wrong problems.

7.1.4 Ways to Reduce Picking Errors

In this subsection, different ways for how the picking errors could be reduced are presented. A first suggestions about visualization to decrease the picking errors due to opened store packs or inner packages. This is followed by a subsection regarding an incentive program is presented.

Visualization

A deficiency which is common for all three customer cases is that it is sometimes difficult for the pickers to understand which item to pick. The picker may be supposed to pick one item at a location, but that item may consist of two levels of inner packaging and it may be unclear which of the three options to pick. Picking the outer parcel when supposed to pick an inner one

results in shortage in inventory. Surplus inventory occurs if the opposite happens. This problem may be avoided if the scanner could provide more detailed information for example showing a picture of the what is supposed to be picked. Not knowing what item to be picked is a problem which occurs much more frequently for new employees, experienced employees are more aware of which inner package to pick unless it is a new item in the warehouse.

Production support (PS) for Customer C spends around 0.4 hours on a daily basis managing opened store pack. Since fixed storage assignment is used at this customer, an alternative to showing pictures of the item in the scanner is to put up pictures of the item to be picked at the location. However, since the customer sometimes updates what is supposed to be considered a store pack, having pictures at the location may be time-consuming to keep up to date and if not kept in order the number of picking errors could increase instead. This is also true for having pictures in the scanner. It is important to only focus on the items that are frequently picked wrongly to be able to keep the maintenance cost at an acceptable level for a system with pictures.

Incentive Program

Implementing an incentive program where the employees receive some kind of reward for having high picking accuracy may result in fewer picking errors. As mentioned in 3.5.6, having an incentive program may be beneficial both in terms of reducing the number of picking errors, which may result in higher customer satisfaction, and reducing warehouse operation costs since time can be saved in managing the consequences of picking errors. It would have to be investigated what levels of picking accuracy should be rewarded for different picking zones and for the different customer cases as well as what an appropriate reward in monetary terms should be. An incentive program may also increase the motivation of the employees, but it has to be properly introduced and supported by supervisors for the program to have a chance for success.

7.2 Transportation and Waiting

Combining all three customers 7.2 hours per day is spent on transportation and waiting. There are two ways to reduce transportation, the first one which is the most desirable, is to remove the need for transportation at all, that is reduce the occurrence of picking errors and the related consequences, which were analysed in section 7.1. The second alternative which is to reduce the time spent on transportation and this is studied in this section.

The time spent on transportation can be reduced in three ways, either by shortening the distance to PS, increasing the speed of which the employees move or reducing the frequency of transportation. The speed is difficult to change since there are speed limits as well as acceptable work pace. The focus will therefore be on reducing the frequency as well as reducing the distance. A suggestion for improved communication is presented first which would reduce the frequency of transports. This is followed by two suggestions for how the distance to get assistance may be reduced.

7.2.1 Improvement of Communication

Contacting PS through phones or the scanner are potential ways which the communication can be improved and reduce the number of transports to PS. If a picker encounters a picking location with shortage in inventory, then instead of traveling to PS, the picker could send a message to PS that there are not enough items on that location and a request for a new location. PS could then immediately when they receive the request look up the item in the WMS and find a new

picking location. PS could then report back to the picker in the scanner about a new picking location. This would save the picker a lot of transportation time. Waiting time could also be reduced since the picker could be able to continue their picking route while PS finds the new location.

The time that may be saved depends on the availability of items and the position of a new location. If a new picking location is available and is located later in the picking route or if the item is out of stock, then almost 100 % of the time estimated for transportation may be eliminated. However, if the new location is not on the route or if a replenishment of a pick location is needed then less time will be saved. The waiting time may be reduced in any case as long as PS can manage the issue before the picker finishes the picking route.

In Table 10 and 11 below, the possible time-savings in waiting and transportation are shown for each customer case. These savings are based on 50 % and 100 % removal of the transportation and waiting time that are caused by shortage in inventory. It is unlikely that a 100 % of the waiting and transportation time can be eliminated and therefore the time-savings are estimated to be somewhere in the interval between 50 % and 100 % of the time. The column with the affected transports shows how many hours of transports which are due to shortage in inventory.

Table 10: Time-savings in transportation

Customer	Time spent on transportation (h)	Affected transports (h)	Reduction of time spent on quality deficiencies
A	3.5	1.4-2.9	4.0-8.0%
B	1.2	0.4-0.8	3.3-6.6%
C	0.7	0.2-0.4	1.2-2.4%

Just as for affected transportation, the affected waiting time show the waiting time which are due to shortage in inventory.

Table 11: Time-savings in waiting

Customer	Waiting total (h)	Affected waiting (h)	Reduction of time spent on quality deficiencies
A	1.12	0.36-0.72	1.0-2.0%
B	0.16	0.07-0.14	0.5-1.1%
C	0.55	0.19-0.38	1.0-2.1%

As has already been mentioned, contacting PS with the scanner only reduces the time spent on transportation and waiting due to shortage in inventory. Waiting and transports due to other deficiencies such as surplus inventory, wrong volume data and damaged goods will not be affected by developing the communication feature.

Improving the communication through the scanner would require an update of the scanner software which might be costly to develop. If the development would be more costly than the time-savings then other ways of communicating, like using phones could be a good alternative. A few employees at customer B already contacts PS with their personal phones if they encounter a location with shortage in inventory.

7.2.2 Location of PS

One way to be able to reduce the transportation time is to study the impact of the location of PS workstations. The location could affect the total transportation time by reducing the travel distance, but it would not affect the waiting time for the warehouse operators.

There are multiple people working as PS for customer A, two at the mezzanine and two to four working at the floor level. Currently PS has one workstation at the mezzanine and one at the floor were PS are located. Since there are at least two PS at each location, PS could be separated into two workstations located at an appropriate distance from each other to limit the transports for the warehouse operators as much as possible. Separating PS into two workstations would reduce the time spent on moving to PS for all deficiencies which require PS assistance, not only shortage in inventory as for the improved communication suggestion. Positioning PS at an optimal location, the distance could be reduced by up to 50 % (1.4 h) for customer A. Separating PS into more workstations requires that all PS can perform all different tasks which may require more education for a period of time. Another disadvantage is that it may be times were PS are not at their workstations which would lead to longer transportations or longer waiting times

There is one person having the role of PS for customer B, located at the floor level. Where to locate PS, on floor level or mezzanine should be determined by where the most problems occur to save both PS and the warehouse operators time. If most problems occur at the mezzanine then locating PS there could save time for the employees at the mezzanine. This would of course increase the transportation time for the employees working at the floor level but overall the transportation time could be reduced. Even though this might save time from the warehouse operators it should also be weighed against the extra time it takes for PS to perform other tasks.

Another aspect to consider before moving PS workstations is that if they are located close to the inbound area it may be possible that it increases the communication between inbound and PS. This increase of communication could reduce the occurrence of some quality deficiencies by getting information as soon as possible about potential issues meaning that PS can manage the issues before it becomes a time-consuming activity later in outbound.

7.2.3 Increased Responsibilities for Employees

Another alternative on how to decrease transportation time is to educate group leaders (GL) in the outbound process on managing some of the tasks performed by PS. GL is for the most part available close to the pickers at the outbound area and if they are taught on how to manage some deficiencies then transportation time could be saved. GL already manages some deficiencies but could potentially be more involved. The time GL is involved in warehouse operations might decrease but the transportation time and overall downtime for the warehouse operators could potentially decrease more. GL could manage deficiencies which directly affect the warehouse operators while PS would still manage the more time-consuming deficiencies and thereby reduce the number of interruptions, which could reduce the time it takes to manage a quality deficiency.

Time may be saved by an increase of responsibility of the pickers as well. Currently, only PS is responsible to check the inventory balance, but this could potentially also be performed by some of the pickers. Pickers that have worked a long time at Schenker and are trusted by PS may check the inventory balance of picking locations during their picking routes. If some pickers are allowed to do inventory checks and improved communication with scanners are implemented together then a lot of time can be saved, both in terms of reduced transportation

and that PS does not need to manage all of the shortage in inventory. A reduction in how many hours that needs to be spent on production support may be possible.

By dividing the responsibilities among more employees, it may be more difficult to understand the real impact from a certain quality deficiency.

7.3 Education

Many hours are spent every week on education of new staff and on develop the existing staff on new work tasks. In Table 12 below the time spent on education for each customer is shown, both during the data collection periods and during 2018, as well as the percentage of employees hired by Schenker. There were no data available for customer C regarding the time spent on education in 2018.

Table 12: Time spent on education and related metrics

Customer	Hours spent on education	% of total hours spent survey	% of hours spent on education (2018)	% of Schenker employed staff
A	6.87	2.5%	6.2%	25%
B	4.38	2.3%	2.2%	20%
C	10.4	3.2%	-	50%

The occurrence of errors is related to the number of new employees according to almost all of the interviews. This means that PS will have to manage a larger number of errors and there is a risk that more errors reach end customer. Usually, inspections of new employees' picking orders are done in the beginning to ensure that everything is in order and to be able to teach them if there are any mistakes. These inspections also take time and are not included in the time spent on education presented in the table.

7.3.1 Rotation of Employees

Customer B has the lowest amount of time spent on education during the data collection and during 2018. Compared to the other two customer cases, rotation of the employees between different tasks is used which requires that the employees have been educated in the different processes and responsibilities. This rotation is similar to the job enlargement presented in 3.5.5 Rotation between different tasks may be motivating for employees since it is an opportunity to learn new things. For the temporary staff, learning new tasks may increasing their chances of being continuously selected by the supervisor for work since they know how to perform different assignments.

Some days there is less to do than others and on such days some employees will have to be cancelled or there will be too many employees for the workload. To make sure that all employees get to work about the same amount, the employees that get cancelled are rotated for customer B. This means that it is not the same employees that get cancelled every time and the temporary staff can expect to have a relatively stable number of workdays. Motivation from being able to perform a number of different tasks and being quite certain that they will get workdays, may be reasons for why the employees may stay longer at this customer case. Therefore, the rotation could reduce the time needed to be spent on education compared to the other customer cases.

7.3.2 Lack of Standardization of Education

Comparing the customer cases regarding education, it was found that each customer case has their own way of handling educational aspects. These includes the length of the first training, the time a picker has available to reach the picking target and other specific activities connected to education.

There are no common rules for how many weeks a new employee has available to reach the goals of a process for the three customer cases. The supervisors evaluate the performance of a new employee for the first time after about one week. The employee may not have reached the goals at this time but if the performance seems promising, the employee may get more chances to prove their capabilities and the supervisor will then evaluate again at a later point. This may go on for a time and sometimes ends up with the employee not reaching the goals and being let go and all the time spent on education has been wasted. On top of that, the employee has performed on a level below the goals, likely with a higher error rate as well.

How much education a new employee receives varies as well for the customer cases. For two customer cases (A and C), a new employee has one person teaching them the entire first day and then just occasional follow up the coming days while at the customer case B the teaching lasts for half a day.

The education has been standardized in some ways for example in who is in charge of it. Previously different people were chosen for educating new employees every time which resulted in varying quality of the education and as a result performance of the employee. The people who are most appropriate to educate are always chosen for educating new employees currently. This ensures that the new employees get approximately the same content and quality of the education. Since the change to having the best educators being in charge of the education, the quality of the process has improved according to the supervisors and the GL.

For one customer case the supervisor wants to meet new staff in person before they start to train a new employee and in this step the supervisor may reject applicants. At another customer case, a list of questions is used to make sure that the employee has understood the important aspects of their work and know what they are supposed to do in certain situations after a few days. The questions were asked some days after the introduction training and this was perceived to be a good method to ensure the quality of the education.

Another potential is to collect more data regarding the daily improvements of a new employee. If the daily improvements for new pickers are collected for all new employees, then after a while Schenker would have a database of daily improvement rates and how many days an employee have worked. Schenker could then compare the performance of the new employee with the database and determine if the improvements are on target to reach the goals. By collecting this data, Schenker could base decisions on whether to reject or give a new employee more time on historical data instead of deciding after arbitrary amount of time and goal fulfilment. This could potentially reduce the occurrence of giving an employee too much time to reach the goals.

The data should be used as a tool to guide decisions regarding new employees but should not replace the interaction between the supervisor and a new employee. There are many different reasons for why a picker's speed may fluctuate and there are always variations in the operations.

In conclusion, a decision whether to keep or reject a new employee should not be based solely on data.

7.4 Warehouse Maintenance

In this section the warehouse maintenance will be analysed in more details. This will be performed by comparing the customer cases, which are then followed by a section regarding how increased collaboration with the customer may affect the time needed to manage this quality deficiency

7.4.1 Comparison of Customer Cases

As presented in chapter 6, there are big differences regarding the time that is spent on warehouse maintenance. The reasons for the difference are analysed with regard to the storage utilisation of the warehouse, the number of stock keeping units (SKUs) and the storage assignment used.

Table 13: Time spent on warehouse maintenance

Customer	Time spent on warehouse maintenance	Storage utilisation %	Storage assignment	SKU:s
A	16.5 h /day	90 %	Class-based	33 401
B	1.1 h /day	61 %	Class-based	6 815
C	1.1 h /day	90 %	Fixed/Random	7 402

From Table 13 above it is clear that warehouse maintenance is a time-consuming activity for customer A especially. Customer A has the highest storage utilisation (together with customer C) and by far the largest number of SKUs. As was mentioned in 3.5.4, a class-based storage assignment may lead to lower storage space utilisation because there has to be empty location available in each class. The storage utilisation is high for customer A and to ensure that there are locations available for inbound goods, PS has to spend a great amount of time on warehouse maintenance. PS move goods between picking locations and buffer location and combines articles of the same goods into fewer storage locations to free locations for new goods in each class. Because the storage utilisation is so high currently, the availability of locations in the different classes is low. The high number of SKUs may also affect the time spent on warehouse maintenance since each SKU may be stored at a picking location and may also take up space in the buffer.

The time spent on warehouse maintenance for customer A can be compared with customer B which has the same storage assignment policy but much lower utilisation of storage space. Since the utilisation is at 61 %, there are available location in each class without PS having to spend hours every day to ensure an efficient inbound flow. As can be seen in Table 13, PS spends about 1.1 hours a day on warehouse maintenance. PS proactively frees up locations in each class by combining items. The time needed for warehouse maintenance would likely increase if the customer would increase their assortment and the storage utilisation rise.

Customer C also has high storage utilisation and there are three main reasons. Firstly, as mentioned in subsection 4.4.1, they are using fixed locations on the picking locations and random storage assignment for the buffer. This increases the utilization of the buffer locations, but if the storage space utilisation of the warehouse is increasing then it will become increasingly difficult to place a pallet in buffer close to its picking location. This means that the time transporters have to spend on moving the goods from buffer to picking location will increase.

Secondly, they can remove picking locations that currently have no stock to create more locations and thereby maintain a higher level of utilization of picking locations. Thirdly, the goods that are stored on behalf of customer C is mainly stored as full pallets. This means that the number of different types storage locations are limited and this means that there is less need of moving articles between locations to make room for certain sizes of incoming article

7.4.2 Closer Collaboration with Customer

As was mentioned in chapter 6, the warehouse maintenance activity is dependent on the customer to a large extent. The customer may require Schenker to store large volumes or increase the number of SKUs in a short time period, and to ensure that there are locations available, warehouse maintenances might be needed. Closer collaboration and communication with the customer may reduce the time performing this task. For example, a new article may arrive in the first shipment in one parcel. If the item is small and light, then it might be considered appropriate to store at the mezzanine. However, a later shipment may arrive in many pallets of the same item which makes the item not suitable for mezzanine and moving the item from mezzanine might be needed. Having known that a large shipment of that item would arrive later would have resulted in the item being stored at floor level right away. This would have eliminating unnecessary warehouse maintenance.

The contract agreement plays a central role in the need of warehouse maintenance. By having a clear agreement between Schenker and the customer regarding the volumes and the quantities that should be stored it would be possible to reduce the need for warehouse maintenance, especially in cases where the customer drastically changes volumes from their forecasts.

7.5 Appraisal Customer A

In this section the appraisal activity that is performed on the mezzanine for customer A is studied in more detail. The activity is in place to make sure that no picking error reach the end customer, by counting all items before they are packed at the packing station. This activity is further studied to compare the time it takes to perform the inspection with the time that is saved when a picking error is detected. This is performed in three steps in the following sections, starting with the time it takes to manage a picking error that reaches the end customer, followed by the time for the appraisal. The last step is to compare the time saved to the time for the appraisal. The analysis is performed using data that was collected during the period (2019-02-18 to 2019-03-01).

7.5.1 Manage Picking Errors that Reach End customer

The time it takes to manage picking errors that reach the end customer consists of three aspects. The time it takes to manage a claim and the time it takes to manage either surplus or shortage of inventory. The analysis in this section will show the time needed for the three steps. It is assumed that a picking error will lead to a claim from the customer that needs to be handled either way.

Surplus Goods

To manage the surplus goods a warehouse operator needs to move the goods to PS workstation, this is a movement that has been estimated to take 0.02 hours. Then PS handles the goods which is estimated to take 0.11 hours. This means that a surplus of one article takes in total 0.13 hours to manage, including the time PS and warehouse operator spends together.

Shortage in Inventory

When a location has shortage in inventory, it creates a transport to PS workstation, which takes about 0.04 hours. Then PS gives information about a new picking location, which is estimated to take 0.05 hours per occurrence and the picker is assumed to wait during this time. Finally, the picker gets a new location and picks the item and continue their picking round. This means that in total PS and picker spends 0.14 hours for each inventory that is incorrect.

Handling Claims

To manage a claim at the mezzanine, PS needs to spend approximately 0.32 hours per claim. This is a number that have been calculated by taking the estimated time that was spent on handling claims and then dividing by the number of claims handled. It has been estimated that both over deliveries and under deliveries results in a claim in the following calculations.

Time Due to Not Detecting Picking Errors

The time that is needed to handle the consequences of not detecting picking errors in this activity is summarized as follows. Number of errors multiplied by the time that is needed to solve the consequences, that is either a shortage in inventory or a surplus inventory. Since there is a difference in time needed to manage surplus inventory compared to shortage in inventory, the distribution between these two areas have been calculated by looking at statistics from 2018. The data show that 70 % of the errors detected in the inspections come from the picker picking too many items, which means that there would be shortage in inventory if it would not have been detected. The time that it would take on average to manage the consequences of a single picking error is therefore calculated to 0.46 hours. The time for not detecting a picking error is calculated in the following way:

$$Time = Number\ of\ claims * \left(Time\ to\ manage\ claims + \begin{cases} (Time\ for\ wrong\ inventory * 0.7) \\ (Time\ for\ surplus\ inventory * 0.3) \end{cases}\right)$$

$$Time = Number\ of\ claims * \left(0.32 + \begin{cases} (0.14 * 0.7) \\ (0.13 * 0.3) \end{cases}\right) = Number\ of\ claims * 0.46$$

7.5.2 Inspections Time Consumptions

For this customer the inspection and the check of the quantity are performed at the same time as the goods are moved from a picking box, into the delivery box. For this calculation it has been estimated that the repacking is a part of the inspection. Another activity that takes time is if an error is detected in the inspections and PS needs to investigate what is wrong with the order.

Appraisal of all Pieces picked

As mentioned in chapter 6, the time it takes to count and repack a single piece is estimated through a time study to 1.9 seconds per piece. This time is multiplied by the number of pieces that were packed on the mezzanine during the period to get the total time for the activity which was 23 hours during the studied period. Even though all pieces should be counted, two errors were not found and led to claims. There could have been more picking errors that were missed but these have not been claimed by the end customer.

Errors Detected in the Activity

If an error is detected in the inspections, then PS is responsible to solve the issue. PS first determines which items are missing or there are too many off, and then either collects or returns items and finally repacks the order. The time it takes for PS was clocked and was compared to

the estimated time that was collected through the survey and an average time was calculated to ten minutes, but it may vary a lot between the errors caught.

7.5.3 Time Spent on Appraising versus Handling Claims

Figure 25 presents the results from the analysis above and shows the correlations between time spent on claims versus appraising related to the percentage of pieces that are inspected.

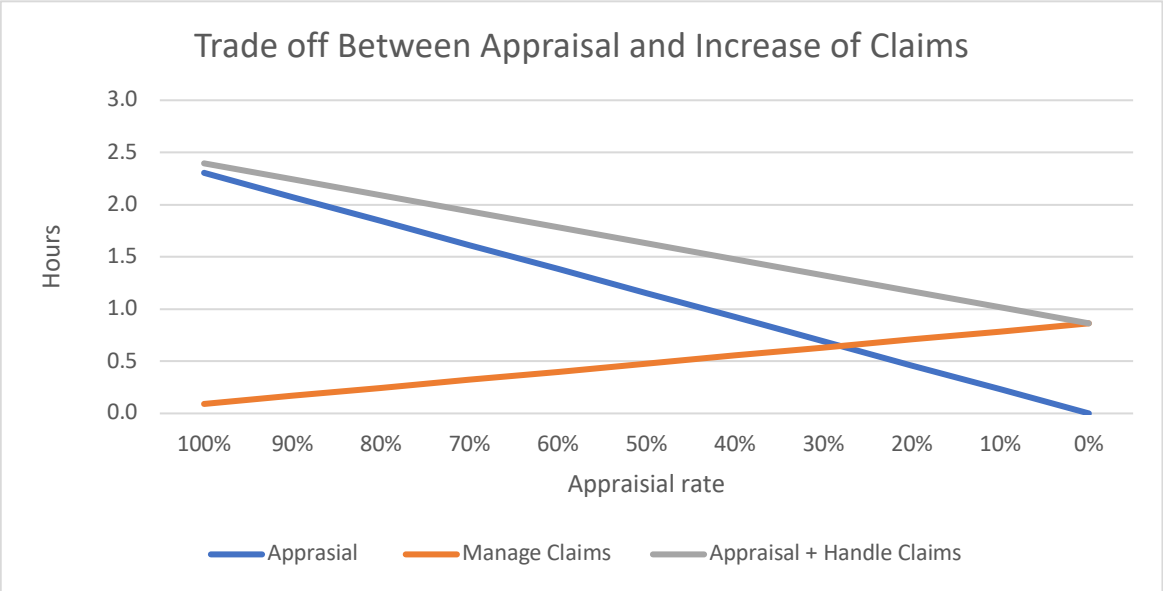

Figure 25: Visualisation of the trade-off between time spent on appraisal and handling claims

As can be seen in Figure 25, the time that is spent on appraising is higher than the expected time needed to manage claims if the appraisal rate is over 20%. Looking at the grey line it is clear that the lowest time consumption is reached when the appraisal rate is 0 %. The average time that is spent on finding and correcting a picking error is 1.5 hours compared to managing a claim which is 0.46 hours. This shows that there needs to be a large decrease in the time for detecting and managing the detected errors to be able to argue for the existence of this activity.

The time-savings that could be realized by removing the appraisal activity should be weighed against three variables. The first and most important from a customer retention view is that if more errors reach the end customers, they will be more dissatisfied and there is a risk that they may leave for another company as mentioned in 3.1.2. The second variable is that there is a bonus malus agreement regarding the picking accuracy. If the accuracy is above a certain level, in this case 99.7 %, there is a bonus added, but if the accuracy drops below it means that the bonus is removed. Lastly, the perception of the importance of picking accuracy among the pickers may be affected if the appraisal activity should be removed since the pickers would then be more responsible to ensure high quality in picking themselves.

By analysing these three aspects in more detail Schenker can make a decision regarding future design of processes like this where a structured and continuous evaluation of appraisal activities can be performed. It is also important to communicate any changes to the warehouse operators to make them aware of why the process should change so that they understand their role in ensuring the picking quality.

7.5.4 Comparison Between Customer A and B

The picking at the mezzanine for customer A was compared with the picking at the mezzanine for customer B. For customer case B, there is no appraisal activity in place, but the picking accuracy is at 99.95 % at the mezzanine which is compared with 99.88 % for customer A should the appraisal activity be removed. However, as was mentioned in 7.1.3, the end customer does not make claims if they have received too many items as often as if they received too few items. 70 % of the picking errors detected in the appraisal for customer A are because too many items have been picked. If the appraisal activity would be removed, a smaller number of these picking errors would lead to claims since the end customer does not always claim when receiving too many items. This would mean that the picking accuracy would be higher than 99.88 % and could be as high as the picking accuracy for customer B, which means the bonus would not be affected. The 23 hours spent on appraisal for customer A could be removed and the picking accuracy may be at a level compared with customer B.

7.6 Customer C Damaged Goods

Damaged goods are a deficiency that occurs at all three customer cases but has the largest impact at customer C. Currently if pickers find damaged goods at customer C, they should fill out a damaged goods form and throw away the damaged items. The filled-out forms are collected by PS who can then update the inventory balance of the location. Another reason for why the pickers should fill out the form is if the goods have been damaged before it reaches Schenker or if the manufacturing quality has been too low, then Schenker does not have to pay for the damaged goods. If this is not filled out, the consequences of damaged goods will be more time-consuming, since it would lead to shortage in inventory.

According to interviews with PS and GL the form is not filled out by all the pickers. A low frequency of reporting leads to a large number of shortages in inventory and a high cost for damaged goods. The main reason for not filling out the form is that it takes too much time from the order picking and negatively impacts the pickers productivity. A potential way to increase the reports of damaged goods could be to report the damaged goods with the scanner similar to what was mentioned in 7.2.1. This would make the reporting a lot faster and PS could get information in real-time and then update the inventory balance immediately or the pickers could update the balance themselves.

Reporting through the scanners could potentially lead to more pickers reporting damaged goods which would result in fewer locations with shortage in inventory and lower cost for Schenker because more goods that are damaged by the manufacturer can be identified. As was mentioned in subsection 4.4.1, customer C uses an automatic replenishment when a location has zero balance. For the automatic replenishment to work efficiently the inventory balance has to be accurate. The automatic replenishment may work better if all the pickers report damaged goods since the inventory balance could be more accurate if PS gets the information faster.

8. Discussion

In this chapter, important aspects of the thesis are discussed. These aspects are the fulfilment of the purpose and research questions, the generalizability of the findings, the suitability of the choice of method, the quality of the data collected, how the limitations of the thesis may have affected the results and finally potential areas which could be studied further are discussed.

8.1 Fulfilment of Purpose and Research Questions

The fulfilment of the purpose and the three research questions are discussed in this section. The research questions are discussed first which guided the research towards reaching the purpose.

The aim of the first research question was to create an understanding for what quality deficiencies currently occur in the operations. A number of different deficiencies were identified which can be used as a starting point if Schenker should wish to analyse other of their customer cases, but further data collection might be needed to identify potential customer specific deficiencies. In the studied customer cases for the thesis, there may exist deficiencies that occur rarely or are integrated in the processes to a large extent that were not found.

The aim of the second research question was to quantify how much time it takes to manage the identified deficiencies. The aim was also to show which deficiencies that have the most improvement potential and which areas that can be studied further. Some deficiencies were not quantified in the thesis. A few of these deficiencies occur due to limitations in the warehouse management system (WMS) and others that are integrated in the processes and these were not quantified through the survey. However, a majority of the deficiencies were quantifiable in the thesis and for those that were not, further qualitative investigation of the impact of these deficiencies were conducted. With the answers to research question one and two, Schenker can keep this understanding of quality deficiencies in mind when designing solutions for new customers. Operations may then be designed in such a way so that the occurrence and/or impact of identified quality deficiencies are reduced.

Finally, the aim of the third research question was to find improvement suggestions for the quality deficiencies. The improvements could potentially reduce the time Schenker has to spend on managing quality deficiencies and make their warehouse operations more efficient. How to implement a potential suggestion was not included and it is up to Schenker to determine the best way to do so.

The three research questions helped to achieve the purpose of the thesis, to increase the understanding of quality deficiencies and provide suggestions for how the operations may be improved to reduce the time-consumption of managing quality deficiencies.

8.2 Generalizability of the Findings

The findings from the three customer cases show differences regarding which quality deficiencies are the most time-consuming to manage. This indicates that the generalizability may be limited concerning the time a certain quality deficiency takes to manage. However, the identified quality deficiencies among the customer cases are similar and are expected to occur in similar warehouse operations. Deficiencies such as picking errors, wrong inventory balance and claims most likely occur at other warehouses, Schenker operated and others as well. There are some aspects that could affect the generalizability. These are for example which WMS that is used and how it is configured, as some identified deficiencies are related to how information is processed in the system. This means that deficiencies that are related to this are not likely to

be identified for other WMS. The order picking system that is used may also affect the findings. Scanners are used at the three customer cases studied, but there are other systems, such as pick-by-voice or pick-by-list. Depending on the system used, the quality deficiencies that may occur in the operations might be slightly different and therefore the findings from this thesis may not be applicable or comparable for a warehouse using other systems.

8.3 Choice of Method and Quality of Data

A discussion about the choice of method as well as the quality of the data is presented here. The main theoretical model is also discussed in this section.

8.3.1 Method for collecting empirical data

Many different data collection methods have been used in the project to get an accurate answer to the three research questions of the thesis. The survey collection was central for reaching the purpose of the thesis and the suitability of the method is discussed here.

The answers to research question two, quantification, and research question three, improvement suggestions, are based on the result of the survey. The alternative to have the survey would have been to conduct time studies to quantify the time spent on deficiencies but this would have been very time consuming and difficult to perform. PS is spread out and are often on the move with forklifts which makes it difficult to follow and collect data from without affecting their work negatively. There is also a risk that some deficiencies which occur rarely may not be detected during a time study of a couple of days. The collected data was confirmed by having interviews with the employees filling out the survey as well as with the supervisor which increased the reliability of the collected data.

The length of the data collection period for the survey is also important for the reliability of the results. A draft of the survey was first handed out and discussed with the employees filling it out and the survey was adjusted until it contained all the relevant quality deficiencies. As has been mentioned, the survey period for each customer was ten working days but this does not include the setup time. This testing activity made sure that the validity of the survey was high. A longer period may have affected the results negatively since the survey was taking time from the employees. In the confirmation interviews, the respondents mentioned that it was slightly annoying to remember to fill out the survey, but they filled out the survey thoroughly with the hopes of improving the operations. A longer period may therefore have decreased the accuracy of the data from the survey. Having the same amount of time for the data collection for the three customer cases made the results comparable.

The collected data from the survey were not statistically significant and data would have to be collected for a much longer time to achieve this. However, the results indicate which areas that are of importance to improve and what activities are time-consuming. Since Schenker had limited data in this area, the collected data still provide valuable insights.

8.3.2 Theoretical Model

The main theoretical model which was used for the thesis was cost of poor quality (CoPQ) and especially Harrington's (1999) model for the concept. There were no model found during the literature search that had previously been used for analysing CoPQ in warehouse operations. Harrington's (1999) model was used to create a structure for how to classify the identified deficiencies, but it needed adaptations to work for the scope of the thesis by the exclusion of indirect costs and external failures. The seven wastes of lean production were also integrated

into the model for the category of non value added to more clearly separate it from the internal error category.

8.4 Impact of Delimitations

There are two main delimitations of the project, that only internal warehouse operations were studied and that value added services were excluded and these are discussed in this section.

8.4.1 Internal Warehouse Operations

Only studying internal operations and not considering the other actors that is, customer, supplier and end customer, meant that some aspects of CoPQ were not included.

The time that end customers and customers have to spend on managing errors from Schenker should then have been included in the quantification and it would have been possible to see the consequences of deficiencies at the next step in the supply chain. This might have affected which deficiencies were considered to be the most significant to improve. Another possible consequence of only focusing on internal operations is that there is a risk of sub-optimising the overall flow. Reducing the internal time spent on quality deficiencies may result in an increase of cost for the customer and end customer. This means that from a customer retention view it is a disadvantage to not have involved this in the scope. If the suppliers would have been included in the analysis it might have been possible to find solutions for some of the quality deficiencies before they reach Schenker.

Most of the suggestions presented in this thesis would only affect internal operations if they would be implemented. The suggestion that the appraisal activity on mezzanine for customer A (presented in 7.5) could be removed is the one suggestion that would directly affect end customer and the increased number of picking errors could lead to higher costs for end customer than the savings Schenker could potentially make. By working with other actors in the supply chain, it might be possible to prevent some quality deficiencies from occurring or reduce the frequency and Schenker would not have to manage them. For example, working more closely with customers to receive better forecast to make it easier to plan the warehouse operations and limit warehouse maintenance. Improving internal operations may have a positive impact on the supply chain since the overall lead time could be reduced.

8.4.2 Value Added Services (VAS)

As VAS is billed at an hourly rate it may not get the same attention from Schenker when it comes to the understanding of quality deficiencies in these activities. This means that the customer may need to pay for these deficiencies, and not Schenker themselves. There are likely VAS activities which generate quality deficiencies and by excluding VAS these were not detected. From a business perspective it is not a big deal from a short-term perspective, as Schenker gets payed by the hour, which means that it is someway covered. With a long-term perspective it may change the attitude among customer if the VAS time increases or stays at a high level. This could mean that they may start to look for other solutions and thereby there is a risk of Schenker losing the customer business.

8.5 Sustainability

The thesis has not had a focus on sustainability, but the findings and suggestions may affect the sustainability of Schenker in a positive way. Economically the suggestions could lead to time-savings in the warehouse operations which have already been mentioned.

In terms of social sustainability, the suggestions may lead to fewer interruptions of the employees working since they could manage some problems themselves without having to contact PS which may reduce stress. Furthermore, if the quality of education should be improved then it would benefit the employees as well since they might learn the process quicker and feel less stressed as well. A reduction of the number of transports made by forklifts as a consequence of working on reducing picking errors or improving communication could be beneficial in form of less risk of injuries and thereby improve the social sustainability.

The main positive impact in an ecological perspective is that if picking errors could be reduced then the number of returns could also be reduced. This would then decrease the number of transports from end customers to Schenker which could reduce emissions.

8.6 Future Research

During the work with the thesis, areas which could be valuable to study in more detail were discovered. These areas concern the way that education is treated in this industry and how the setting of targets may impact the warehouse operations quality. There are also other areas which could be studied such as the use of VAS and technological systems used to achieve higher quality.

8.6.1 Education

One area which is time-consuming and directly related to the occurrence of quality deficiencies is education. As has already been mentioned many hours every week are spent on education. The education takes place differently at the three studied cases and there is potential to study this further and find a good setup for education. Customer B has the lowest amount of time spent on education, but this does not necessarily mean that the education is performed in the best way for customer B. One important aspect is employee retention which affects the need for education. As was mentioned in 7.3.1 rotation between different tasks is used for customer B which may make employees stay for a longer time. The fluctuation in the customers demand may also affect the need for education, meaning if the customers business with Schenker is growing, declining or staying the same. If for example the business is growing, then more hours may have to be spent on education since new employees are needed. The portion of staff from staffing agencies and Schenker's own staff may also affect the need for education. It is tricky to determine which customer has the best education and for this thesis, the educational aspects were not analysed in depth. It is therefore recommended that Schenker studies their educational activities in more detail and should include more than three cases and of different sizes. It may then be possible to find a standard for the educations as was mentioned in 7.3.2.

8.6.2 Setting of goals

The goals for the warehouse operators may have an impact on how likely it is that quality deficiencies are managed. For the pickers, the goal is to pick at least a certain amount of order lines every day while maintaining a certain picking accuracy. This means that everything else that does not involve reaching these goals are wasteful for the pickers and affects their productivity negatively. For example, for customer C the pickers are supposed to fill out a form if they encounter damaged goods, but this is not done by many pickers since they have to spend picking time on an activity that does not contribute to them reaching their goals. But if everyone would report damaged goods, then the inventory balances would be correct more often and this would help all the pickers to reach their goals. This shows that the goals may hinder proactive work to reduce some quality deficiencies. Therefore, it would be an interesting area to conduct

further research about. How pickers may be measured in other ways that can include their work regarding quality deficiencies. The incentive programme for picking accuracy mentioned in 7.1.4 may negatively affect proactive work to reduce quality deficiencies.

9. Conclusion

The purpose of the thesis was to increase the understanding of quality deficiencies occurring in the internal warehouse operations and how the warehouse operations can be improved to reduce the time-consumption of managing deficiencies. To be able to answer the research questions interviews were held, observations performed, and quantitative data collected through a type of survey as well as through time studies.

The answer to the first research question of the thesis: *What quality deficiencies occur at Schenker's warehouse operations and how can they be classified?* is that there are many quality deficiencies that may occur in the operations. Some of the quality deficiencies are due to IT or the contract with the customers and the time consumption for these have not been quantified, while most of the quality deficiencies are activities which happen as a result of a failure or error either in the internal operations or by the suppliers. The relationship between different deficiencies were also identified since one failure may cause many activities to handle it. Most of the identified deficiencies are common for the three customers such as picking errors and shortages in inventory.

For the second research question: *How much time is spent on managing quality deficiencies?* the time it takes to manage these deficiencies were quantified through a survey and estimations. The method used for this thesis with survey as the main quantitative data collection method may be used for any warehouse operations. The survey method requires that the operations and what deficiencies that may arise from them is well understood before it can be undertaken. Between 5.5% and 12.5 % of the time spent on warehouse operations are related to quality deficiencies. One finding showed that education is an activity which takes a substantial amount of time for all three customer cases. Transportation takes a lot of time for customer A and B while warehouse maintenance takes a lot of time for customer A only.

Finally, the third and final research question: *How can the time spent on quality deficiencies be reduced?* In answering this question, suggestions for improvements for handling quality deficiencies were analysed. Transportation due to the pickers encountering a problem which they cannot solve on their own and having to get assistance wastes a lot of order picking time and should be avoided as much as possible. Developing a system where the picker can solve the most commonly occurring problems themselves can save much transportation time.

Schenker could analyse the improvement suggestions on their own to determine whether the suggestions are worth implementing or not. They are also recommended to conduct further research in some areas, especially education. Many hours are spent on education every year, but even though it is such a time-consuming activity there is no standard for how to perform it. Studying education in more detail for more of Schenker's customer cases to determine how it is done and what works best could be valuable. Also, collecting data from new employees could help guide follow up of the new employees. Reduced number of hours spent on education as well as higher quality of it leading to more productive warehouse operators could be a result of having guidelines for education but as has already been mentioned, this should be studied further.

References

Arunagiri, P., & Gnanavelbabu, A. (2014). Identification of Major Lean Production Waste in Automobile Industries using Weighted Average Method. *Procedia Engineering, 97*, 2167-2175.

Barczak, G. (2015). Publishing Qualitative versus Quantitative Research. *Journal of Product Innovation Management, 32*(5).

Bateman, M. J., & Ludwig, T. D. (2004). Managing Distribution Quality Through an Adapted Incentive Program with Tiered Goals and Feedback. *Journal of Organizational Behavior Management, 23*(1), 33-55.

Battini, D., Glock, C. H., Grosse, E. H., Persona, A., & Sgarbossa, F. (2016). Human energy expenditure in order picking storage assignment: A bi-objective method. *Computers & Industrial Engineering, 94*, 147-157.

Berdicchia, D., Nicolli, F., & Masino, G. (2016). Job enlargement, job crafting and the moderating role of self-competence. *Journal of Managerial Psychology, 31*(2), 318-330.

Berg, B. L. (2001). *Qualitative Research Methods for the Social Sciences* (Vol. 4). University of Michigan: Allyn and Bacon. Retrieved 01 23, 2019

Bowling, A. (2005). Mode of questionnaire administration can have serious effects on data quality. *JOURNAL OF PUBLIC HEALTH, 27*(3), 281-291.

Bryman, A. (2011). *Samhällsvetenskapliga metoder* (2nd Edition ed.). Malmö: Liber.

Castillo-Villar, K. K., Smith, N. R., & Simonton, J. L. (2012). The impact of the cost of quality on serial supply-chain network design. *International Journal of Production Research, 50*(19), 5544-5566.

De Koster, R., Le-Duc, T., & Roodbergen, K. J. (2007). Design and control of warehouse order picking: A literature review. *Design and control of warehouse order picking: A literature review. European journal of operational research, 182*(2), 481-501.

Dubois, A., & Gadde, L. E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, 553-560.

Emerald Publishing. (2018, Januari 23). *How to... use secondary data and archival material*. Retrieved from emeraldgrouppublishing.com: http://www.emeraldgrouppublishing.com/research/guides/methods/archival.htm?part=4

Feigenbaum, A. V. (1956). Total Quality Control . *Harward Business Review*, 93-101.

Fejes, A., & Thornberg, R. (2016). kvalitativ forskning och kvalitativ analys. In A. Fejes, & R. Thornberg, *Handbok i kvalitativ analys* (pp. 16-39). Malmö : Liber.

Given, L. M. (2008). *The SAGE Encyclopedia of Qualitative Research Methods.* London: Sage Publications .

Grosse, E. H., & Glock, C. H. (2015). The effect of worker learning on manual order picking processes. *International Journal of Production Economics, 170*, 882-890.

Grosse, E. H., Glock, C. H., Jaber, M. Y., & Neumann, W. P. (2015). Incorporating human factors in order picking planning models: framework and research opportunities. *International Journal of Production Research, 53*(3), 695-717.

Gu, J., Goetschalckx, M., & McGinnis, L. F. (2007). Research on warehouse operation: A comprehensive review. *European journal of operational research, 177*(1), 1-21.

Harrington, H. (1999). "Performance improvement: a total poor-quality cost system". *The TQM Magazine* , 221-230.

Hultén, H. (2018). Prispress och specialisering präglar svensk tredjepartslogistik. *Intelligent Logistik*, pp. 28-31.

Kauda, J. (2012). *Research Methodology: A Project Guide for University Students* (1st ed.). Fredriksberg: Samfundslitteratur.

Kent, R. (2016). *Quality Management in Plastics Processing - Strategies, Targets, Techniques and Tools.* Elsevier.

Krishnan, S. K. (2006). Increasing the visibility of hidden failure. *Measuring Business Excellence*, 77-101,.

Lewis-Beck, M. S., Bryman, A., & Liao, T. F. (2004). *The SAGE Encyclopedia of Social Science Research Methods.* London: Sage Publications.

Longoni, A., & Cagliano, R. (2018). Sustainable Innovativeness and the Triple Bottom Line: The Role of Organizational Time Perspective. *Journal of Business Ethics, 151*(4), 1097–1120.

Muijs, D. (2010). *Doing Quantitative Research in Education with SPSS* (Vol. 2). SAGE.

Nicholas, J. (2011). *Lean production for competitive advantage: a comprehensive guide to lean methodologies and management practices.* Productivity press.

Pyzdek, T. (2003). *The Six Sigma Handbook, Revised and Expanded.* United states of America: McGraw-Hill Education.

Roodbergen, K. J., & De Koster, R. (2001). Routing methods for warehouses with multiple cross aisles. *International Journal of Production Research, 39*(9), 1865-1883.

Roodbergen, K. J., Sharp, G. P., & Vis, I. F. (2008). Designing the layout structure of manual order picking areas in warehouses. *IIE Transactions, 40*(11), 1032-1045.

Rosén, P. (1999). *Tredjepartslogistik i svensk industri - en kartläggning.*

Rowley, J., & Sbaffi, L. (2018). Academics' attitudes towards peer review in scholarly journals and the effect of role and discipline. *Journal of Information Science, 44*(5), 644-657.

Rubenowitz, S. (2004). *Organisationspsykologi och ledarskap.* Lund: Studentlitteratur AB.

Sörqvist, L. (1997). EFFECTIVE METHODS for measuring the cost of poor quality. *Measuring Business Excellence, 1*(2), 50-53.

Savitz, A., & Weber, K. (2014). *The triple bottom line [electronic resource] : how today's best-run companies are achieving economic, social, and environmental success--and how you can too.* San Fransisco: John Wiley & Sons.

Slack, N., Chambers, S., & Johnston, R. (2010). *Operations management* (6th ed.). Harlow: Pearson publishing.

Specter, S. P. (2017). Retailers use 3PLs to chase Amazon: 3PLs tackle e-fulfillment challenges with service and market specialization as well as investments in flexible automation. *Modern Materials Handling, 72*(10), 56-60.

WCED. (1987). *Our Common Future - Report of the World Commission on Environment and Development.* World Commission on Envrionment and Development. Retrieved from http://un-documents.net/our-common-future.pdf

Wienclaw, R. A. (2017). *Salem Press Encyclopedia*. Retrieved from Interviews: http://proxy.lib.chalmers.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=ers&AN=89185555&lang=sv&site=eds-live&scope=site

Zandin, K. B. (2001). *Maynard's Industrial Engineering Handbook* (5th ed.). New York: McGraw-Hill Education.

Zimak, G. (2000). COST OF QUALITY (COQ): WHICH COLLECTION. *ANNUAL QUALITY CONGRESS PROCEEDINGS*, (pp. 18-24). Indianapolis.

Appendix I – List of Interviews

In this table, all employees that were interviewed can be seen. Adding to this it also shows how many from each function that was interviewed and what the purpose of the interview were.

Position	Customer	Interviews for RQ1	Confirmation interview of collected data from the survey
Group leader	A	3	
Supervisor	A	1	1
Production support	A	2	2
Stock manager	A	1	
Control tower	A	1	
Picker	A	1	
Group leader	B	3	
Supervisor	B	1	1
Production support	B	1	1
Control tower	B	1	
Superuser	B	1	
Group leader	C	2	1
Supervisor	C	1	
Production support	C	2	1
Superuser	C	1	
Control Tower	C	1	

Appendix II– Interview Guides

The interview guides used in the project are presented in this Appendix. The first interview guide was used to identify quality deficiencies and understand the processes in the warehouse. The second guide was used to confirm the data collected from production support (PS) and group leaders (GL).

Interview Guide 1 – Process understanding and Identification of quality deficiencies

The interviews for identification and process understanding were of semi-structured meaning that other questions may have been asked that are not part of the interview guide. In the beginning of the interviews, the purpose of the thesis was explained. The definition of quality deficiencies that was used in the project was also presented.

General questions

- What is your position in the company?
- Could you describe the flow in the scope of your responsibilities?
- What are your daily tasks and responsibilities?
    - Could you describe an average workday?
    - What are the most time-consuming activities?
- How long have you worked at Schenker?
    - How long have you worked at your current position?
- Has there been any significant changes in the operations recently?
- How would you define quality?
- To what degree are you and other employees involved in improvements?
- What measurements are used today to measure the quality of the operations?
- Are there any measurements for quality deficiencies?
- Are any of the activities you perform billed as VAS to the customer?
- If you encounter a problem you cannot solve, who do you turn to for assistance?

Inbound/Outbound

- What quality deficiencies may occur in inbound/outbound?
    - How much does time does it take to manage said deficiency?
    - How often does said deficiency occur?
    - What are possible consequences of the deficiency?
- Is the deficiency measured today or how could it measured?
    - If the deficiency is not measured, why?
- What are the most commonly occurring deficiencies that affect the production?
- Are there any inspections in the production?
    - How often are they done?
    - If errors are detected, what happens?

Interview Guide 2 – Confirmation of Survey

The format for this interview was more structured were all questions were asked

- Have the data collection period in your opinion represented a normal week?
    - Are there any major differences from an average week?

Which are the three quality deficiencies that have needed the most time to manage during the data collection period?

According to the interviewee	% share of their time	According to the collected survey data	% share of the time spent on manage quality deficiencies

Unaccounted time from the survey

- There is some time that have not been documented in the survey comparing to what should be a full work day. What would you say are the reasons for this variation and the missing hours?
- Have you performed other work task and forgotten to change the time log?
- Is there variation in the number of issues occurring in the production?
    - Other reasons?

Confirmation of transport and waiting

Quality deficiency	Picker need to go to PS	Picker needs to wait for PS
Quality deficiency 1	x	X 2 min
Quality deficiency 2		
Quality deficiency 3	x	

- For which of the deficiencies in the table above does the picker need to move to PS to get help?
- For which of the problems in the survey should the picker wait for PS to solve the problem before the picker can return to work?
- Does the picker frequently have to wait before they are receiving help from you?

Appendix III – Example of Survey Layout

This is a template for the survey, and it was adapted to each customer case.

Description of Quality deficiency	Occurrences per day	Estimated time spent per day
Wrong inventory balance		
Supplier error		
Volume error		
Picking error		
VAS Activities	Number/day	Time spent
Work orders		
	Number/day	Time spent
Manage claims		
Surplus articles		
Warehouse maintenance		
Other issues		