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Master Degree Project in Logistics and Transport Management

Investigating the move from a traditional warehouse classification to a more sophisticated one: a case study of ABB Jokab Safety AB.

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Graduate school

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Abstract

Title: Investigating the move from a traditional warehouse classification to a more sophisticated one: a case study of ABB Jokab Safety AB
Thesis Degree: Master degree in Logistics and Transport Management
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Purpose: The purpose of this Master thesis is to investigate how a company could develop a traditional warehouse strategy into a more sophisticated one, taking into consideration the criteria identified by the case study company as being the most important. The initial goal of this report is to suggest a way of calculating and categorising items, by developing a framework with guidance and recommendations. To manage this classification, the most suitable method leading to a minimised stock value will be investigated.

Research Questions: How could a traditional warehouse strategy be moved to a more sophisticated one in order to reduce the stock value? And what is necessary in order to implement a multi-criteria method for doing so?

Methods: The research involves an experimental case study that combines a qualitative with a quantitative approach. The main sources of data are both primary and secondary, in the form of observations, pilot study and preliminary tests, which are presented in the empirical analysis.

Main findings: To develop the warehouse strategy analysis, a mapping of the current situation is crucial in order to find gaps. The research has identified that an application of the Ng-model is the most appropriate method to reduce the current stock situation. The process focuses on the main objective of the implementation as well as the process of motivating and involving the employees.

Key words: ABC analysis, warehouse management, inventory management, stock value, warehouse strategies, multi-criteria classification, demand, lead time, supply price, Ng-model.

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Athanasia Mitraka Carolin Svensson Johnson

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Table of abbreviations

ABB - *Asea Brown Boveri*

DEA - *Data Envelopment Analysis*

JIT - *Just In Time*

MCIC - *Multi-Criteria Inventory Control*

SC - *Supply Chain*

SKU - *Stock Keeping Unit*

WMS - *Warehouse Management System*

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1. Introduction

In the introduction chapter of this thesis the background, research questions, purpose and delimitation will be presented, with the purpose to introduce the subject in a sequential way for the reader.

1.1 Background

Supply chain management considers the relationship among activities, information, and resources a company needs in the process of movement of products and services from supplier to customer. Often it is in terms of retailers, warehouses, distributors and manufacturers (Michna and Nielsen, 2018). Two basic processes are usually involved and integrated; the production planning and inventory control process, and the distribution and logistics process (Tsiakis, Shah and Pantelides, 2001). A warehouse is generally involved in several stages of the supply chain, possessing an essential part in it. Trends as market volatility, product range and customer lead time have a direct impact on the warehouse and the requirements of it (Rushton, Croucher and Baker, 2010). To regulate these trends the warehouse management has evolved into a vital role leading to business success, whereby a company needs to operate efficiently to remain competitive. The complex task of increasing the efficiency in a warehouse is a part of a strategy that plans and controls decisions, and processes in structured ways (Faber, Koster and Smidts, 2013).

For items which already exist on the market, the main activity that adds value for a company is their instant availability. This process of checking the availability of items on stock is called inventory control, which provides to the company the ability to manage the customer service, the manufacturing activities, the logistics operations, and the distribution function in order to meet the demand. Inventory´s management overall target is to control the stock value, which means to reduce the supply price and the quantity of stockholding, which could eventually optimise the whole supply chain (Wild, 2018). Faber, Koster and Smidts (2013) claim that the purpose of warehouses is to decide upon the way and the process followed to ensure the optimal outcome.

Warehouse management alone is not enough to achieve maximum effectiveness with the minimum possible effort. For this reason, researchers created warehouse strategies to manage the combination of best availability, minimum inventory, and least time of controlling and planning products in the warehouse (Faber, Koster and Smidts, 2013). Wild (2018) claims that establishing a classification of products could ease the process of achieving a target. For example, if the goal is to decrease the stock value, a classification could contribute to a better control of the processes. That would result in actions the company could do to decrease the stock value.

In general, the classification of products is characterised by the criteria taken into consideration. Based on this diversity, there is the single criterion that takes only the unit cost into consideration and multi-criteria classifications that mixes several aspects as lead time and demand. The fact that the traditional ABC analysis only considers a single criterion and excludes other aspects is its biggest disadvantage (Yu, 2011). The traditional ABC classification is inspired from the pareto philosophy, which aims to control the inventory stock (Flores and Whybark, 1987). Unlike the single criterion method, the multi-criteria studies several aspects, as lead time, inventory cost, number of per year requests, etcetera (Park, Bae and Bae, 2014). Teunter, Babai, and Syntetos (2010) support the most common ranking criteria to be the demand value and the demand volume. Liu and Wang (2016) describe that companies need to consider developed methods, that includes the increase of personalized service. Traditional systems have a low ability to fulfil the demand for personalised needs for the customers. This is also stated by Tsiakis, Shah and Pantelides (2001), where a supply chain in a competitive environment should manage cost, inventories, and investments in the most efficient way.

To proceed with the purpose of this thesis, the authors decide to take a closer look into a case study company. The case study company chosen was ABB Jokab Safety AB, a department of ABB multinational enterprise, focusing on low voltage products. The company's initial target is the development of innovative products and technological solutions for machinery safety. Having as a first aim to develop the existing traditional ABC classification into a more sophisticated one, the authors conducted a detailed investigation of the company's current situation. A sophisticated model is defined by the authors to be a model that is more effective comparing to the current system and takes in mind necessary aspects in order to better be competitive on the market. While the research was managed, a lack of an ABC classification as it is described by the literature was noticed. The purpose of the thesis changed several times after discussions conducting with both internal and external supervisors. The conclusion of these discussions helped the authors to

propose an alternative sophisticated method of classification with respect to the research's and the company's needs, which would apply to the authors' interests. Researching many alternative methods, the authors ended up with the Ng-model, a non-programming linear optimisation classification, which would satisfy the company's current situation and at the same time be easy to apply by managers. Combining the case study company with the solution of the Ng-model would be beneficial since it provides a real example on how to classify a warehouse in order to achieve an ABC classification. At this point, the authors of this thesis did not only search through the theory and come up with the most appropriate model but also applied this model to the company. This application was based on real-life company's numbers, which would not only provide solutions but also could be used as a tool to proceed with further research in the future. Last but not least, based on the mapping of the current situation, the authors proposed to the company efficient ways to implement the model and proved to them the beneficial outcomes that could be derived from this model, which would eventually result in a decrease of the stock value.

1.2 Purpose

The purpose of this master thesis is to investigate how a company could develop a traditional warehouse strategy to a more sophisticated one, taking into consideration the most important criteria. The initial goal of this report is to suggest a way of calculating and categorising items, by developing a framework with guidance and recommendations. To manage this classification, the most suitable method leading to a minimised stock value will be investigated.

1.3 Research Question

It is a complex mission to balance the variation of customer demand, lead time and supply price, and remain flexible without over-building inventory stock. By conducting a case study in ABB Jokab Safety AB, the authors' intent is to answer the following research questions:

- How could a traditional warehouse strategy be moved to a more sophisticated one in order to reduce the stock value?
    - What is necessary in order to implement a multi-criteria method?

1.4 Problem Description

The warehouse management system (WMS) has become important in recent years, mainly because of the requirements deriving from the market and the competitors, as well as the customer demand. There is often a continuous pressure on the warehouse management for improvements, where cost reduction and increased efficiency are mainly highlighted (Blanchard, 2009). In order to remain competitive, a warehouse needs to balance its stock and at the same time remain efficient in both the upstream and the downstream flows of the chain (Wild, 2018). A single criterion, as already mentioned, takes one aspect in mind in the classification process. This could be problematic for a warehouse, as other combined aspects could be of higher relevance for the company. A company should adapt its own classification strategies based on its own processes, needs, customer demand and supplier's availability (Yu, 2011).

Companies are highly dependent on data, mainly because the operation of collecting the right information in the right form is important to accomplish future analysis. Even if the right information is collected, the way they are presented is conclusive (Brinch, 2018). The most common mistake companies are doing while collecting data is that they save too much irrelevant statistics. All this information may never be used since it is not stated on forehand what they should do with them. This could lead to perceiving the great number of statistics as a disadvantage since the time-consuming process needed to analyse them does not add value (Wang, Gunasekaran, Ngai and Papadopoulos, 2016).

The case study that has been used in this master thesis is the warehouse situation existing in a company. The company has different categorisations, but no one includes a combination of customer demand, the lead time and the supply price. According to the case study company, a lumpy demand, a wide range of products and different lead times exist, which complicates a categorisation. Even though the objective was to create an ABC-XYZ strategy, the ABC classification was not applied currently in the company. This situation created the opportunity to structure the existing data and provide a framework with guidance. Questions as which data is required and in which form, and how to manage the data, got relevant and set limitations for the study. The Ng-model suited in the current situation as it did not require any data programming and the criteria were adaptable. Therefore, could criteria that were necessary for the case study be chosen and a formula delivered in the framework that could be managed without high knowledge about math, statistics or programming.

1.5 Company description

Asea Brown Boveri (ABB) is a Swedish-Switzer multinational enterprise with a focus on technological solutions within quality and efficiency, which operates in roughly 100 countries and has employees of around 140 000 people (ABB, 2018a). In Sweden, ABB AB is localised in 30 places of which 10 of them are business centres i.e. sales hubs. ABB AB is a worldwide company that has the main objective to offer quality products by involving in several markets as energy, industry, transportation, and infrastructure (ABB, 2018b). The vision is to remain a global leader within automation technologies that will increase the customers' performance and lower the impact on the environment. By providing a range of products, systems, solutions, and services the initial goal is to optimise the productivity, reliability and enhance energy efficiency (ABB, 2018c). ABB AB is following megatrends as investing in solar and wind power as well as pushing the industry of the fourth revolution of the internet.

1.5.1 ABB Jokab Safety AB

Jokab Safety AB, now ABB Jokab Safety AB, was founded in 1988 in Kungsbacka and Malmö, Sweden by Mats Linger, Torgny Olsson and Gunnar Widell, with the vision to become the most widely known partner for machine safety (ABB, 2013). ABB AB bought Jokab Safety AB company on 10th March 2010 and since then it became ABB's AB major department dealing with safety issues. ABB Jokab Safety AB has about 120 employees in America and Europe. The major focus is on the practical application of safety requirements in the production environment. Jokab Safety AB's core business is to develop innovative products and solutions for machinery safety (ibid). Out of the four division of ABB AB, the electrification products, the robots and motion, the industrial automation and the power grids, the ABB Jokab Safety AB belongs to the department of the electrification product and more detailed in the low voltage products division. Since 2000, Jokab Safety AB's work is based on the global directives and standards within the International Organisation for Standardization. ABB Jokab Safety AB has as a challenge to deal with international safety standards and European standardisation work equally.

1.6 Delimitations

According to Collis and Hussey (2014), the delimitations of a study are defined as the boundaries. The delimitations of this study are necessary to be stated, to clarify the constraints of the research process. To test the multi-criteria Ng-method on the case study some delimitations on existing

product range were needed. In the current situation, each department independently categorise the products in its own way, which fulfils its incentives. Based on the company's product life cycle management list, where products are divided into active, classic, limited and obsolete phases, the focus will be on the active products. Active products were chosen as these either have recently entered the market or fulfil the demand for a lot of customers. The strategy the case study company follows, differs the lead times of the products based on the order amount from the customers. In this specific research, the lead time per item will be perceived stable no matter the order amount.

1.7 Thesis Disposition

The chapters of this study were separated in a logical way into seven parts; Introduction, Literature Review, Methodology, Empirical Findings, Discussion, Conclusion and Future Recommendations. To make the thesis deposition easily understood for the reader, the authors visualise the outline of the thesis in figure 1.

In the Introduction chapter, the authors include the background, the description of the problem, the purpose of the research, the research questions and the case study company description. The connected with the topic literature was researched in the Literature Review chapter, and constructed based on the knowledge derived. For the Methodology chapter, an overview of the methodology used in the research was conducted, including topics of data collection, reliability, validity and generalisability.

The fourth chapter was named by the authors as Empirical Analysis, as it includes the case study company and some important information collected by observations and interviews conducted. The data collection was presented, and a pilot study and preliminary test were performed. Knowledge from the Literature Review and the Empirical Findings chapters was combined and discussed in the Discussion chapter. In the Conclusion chapter the main idea of the thesis was summed up and the research questions were answered. In the Future Recommendation chapters, the authors proposed some recommendation for the future for the case study company to resolve the current situation and some suggestions for further research.

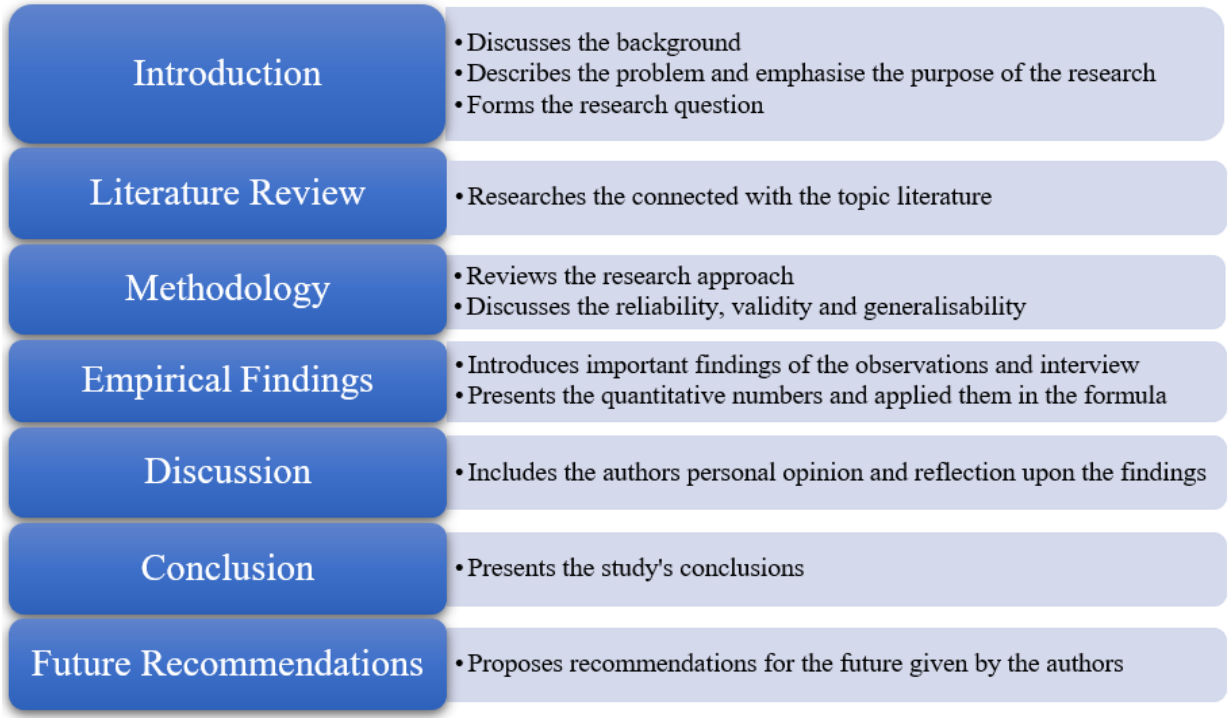


Figure 1 - *Outline of the study, developed by the authors.*

1.8 Research Flowchart

This subchapter presents the process the authors of this thesis went through and has as a purpose to increase the readers understanding on what the research questions are based on.

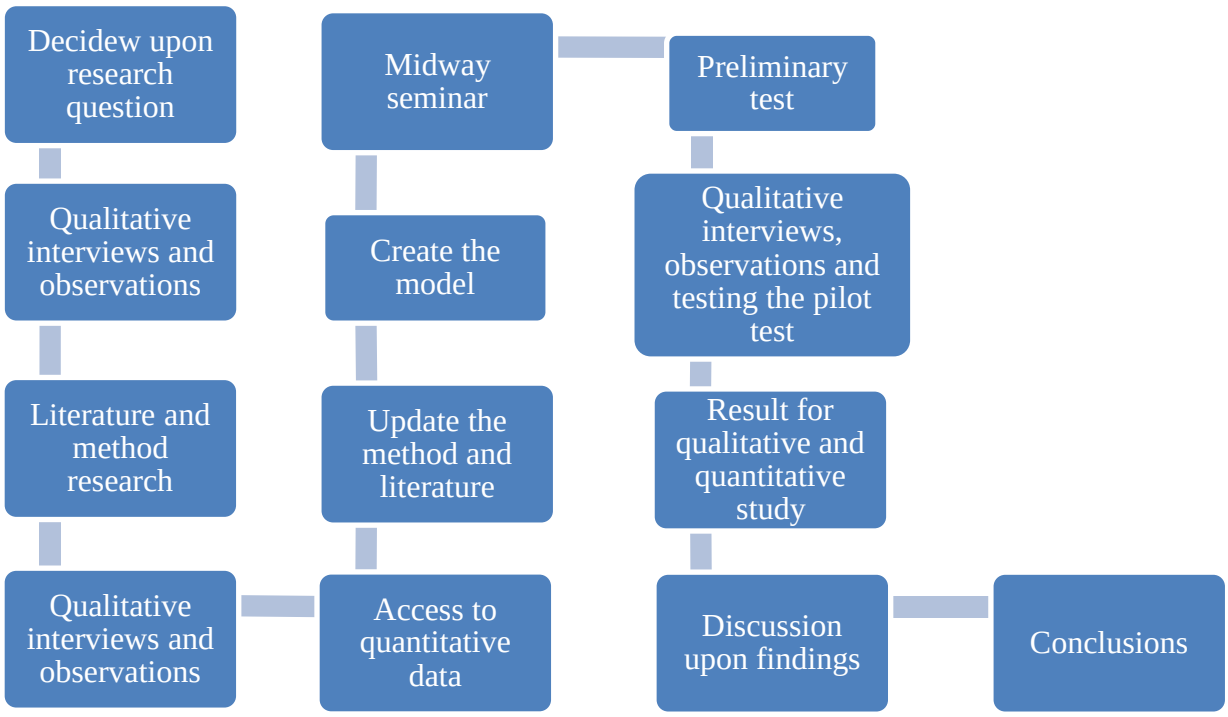


Figure 2 - *Research Flowchart, developed by the authors.*

2. Literature review

This chapter will present the necessary theory connected with the topic and the process of answer the research questions. Subjects as warehouse management, purchasing processes, inventory, demand, supply price, lead time, classification, single- and multi-criteria classification, Ng-model, and linear optimisation models are included and analysed.

2.1 Warehouse management

Wild (2018) claims that an organisation needs to be able to offer useful products for an acceptable price within a valid time frame, which requires collaboration between several departments. A supply chain (SC) is considered to be the settlement where activities, information and resources manage a movement of products or service from suppliers to customers (Michna and Nielsen, 2018). At the same time, a supply chain is a transitional line between the different members which directly affects the cost and the service (Faber, Koster and Smidts, 2013). Information integration in the logistic departments is described to improve the information system, as it develops their collaboration. The authors Shi, Li, Yang, Li, and Choi (2012) support that the more a company is investing in information technology the better economic benefits and the higher level of customer service will result. Liu and Sun (2011) state that all parts of the SC, should cooperate and share information as it is necessary to create smooth communication. Information flow needs to consist of real-time, direct and accurate information to start the logistic chain. A SC information chain needs to transmit the right information in a preferred level and it should be accessible by the right people, be accurate and in time. It should be also mention that the prevention and the control of data leakage should be continuously done, and could be accomplished by the selection of the right communication tools (ibid). Brinch (2018) expand this idea by supporting that not only the right information should be collected, but also it needs to be presented in an optimal way.

The warehouse is one part of the supply chain, where stock and inventories are stored and transport planned in order to fulfil the customers demand (Michna and Nielsen, 2018). Two basic processes often appear in a warehouse. Firstly, the production planning and inventory control process that manage manufacturing, storage, and interfaces. Secondly, the distribution and

logistics process, which regulates how products are collected and transported from warehouse to retailer (Tsiakis, Shah and Pantelides, 2001). Faber, Koster and Smidts (2013) describe that the warehouse has a complex task since it has to manage all the stock keeping units (SKU), the variation of the warehouse's process outcome and the number of order lines prepared by the warehouse per day. The authors continue by connecting business success with the warehouse, as it affects the SC costs and service. Even though Tsiakis, Shah and Pantelides (2001) conclude that the logistics costs are dependent on company, sector, and country, Rushton, Croucher and Baker (2010) claim that they are directly affected by the logistic structure and the sophistication of the distribution system. The correlation between planning and control in a company impacts the logistics structure, where both have necessary aspects to run in a practical manner. Planning should ensure that the processes could run properly and in an efficient way, whereby control is focusing on operating in the right way. As Faber, Koster and Smidts (2013) discuss, the planning and control need to be organised in order to meet the developed challenges, which differs due to the market they are operating on.

2.1.1 Purchasing process

Rushton, Croucher and Baker (2010) emphasise the purchasing process and the supply as key factors for a company's success. Mihir and Kailash (2005) describe that organisations often manage both big and small purchases, where the big purchases are defined as well-planned, high volume and value, compared to small purchases that are defined as low volume and value, high variety, low technical complexity, and unexpected use. These flows are discussed to be handled with different strategies. Rushton, Croucher and Baker (2010) support that an improvement of the efficiency in the purchasing process could result in increased profitability as the supply chain develops. Having the appropriate amount of items, at the right time, in the right place, in the appropriate quality, and in the agreed price is something of great importance for the companies. According to Rushton, Croucher and Baker (2010), establishing production systems, which reducing all unnecessary activities, could not only be beneficial for the company, but also for the relationship they establish with their suppliers and their customers.

As Gunasekaran (1999) supports, this Just In Time (JIT) technique along with the quality management not only successfully diminish the inventory but also develop efficiency in production and manufacturing processes. There are many scenarios based on purchasing management which aim to reduce the lead time and to create a more efficient purchasing process. Schonberger and Gilbert (1983) refer to a number of tactics and strategic benefits stemming from

the adoption of this kind of purchasing model, such as inventory control, improved productivity, reduced carrying cost, reduced purchase-order cost, improved quality, improved relationship with suppliers and customers, etcetera. Often, in companies which do not follow the JIT purchasing strategy, a crossover scenario occurs. The phenomenon of crossover scenario appears when a replenishment takes place in another period than when it is ordered (Michna and Nielsen, 2018), which results in that the receiving order cannot match the requested one.

Mihir and Kailash (2005) refer to the lead time as a key factor impacting the purchasing process. According to them, as many companies prefer to organise the purchasing processes based on the orders, since the lead time plays a catalytic role in these situations. To manage the purchasing procedure, companies usually rely on a forecast. Rushton, Croucher and Baker (2010) characterise the forecasting as a tool to estimate future requirements for a product or an SKU targeting to satisfy customer demand as precise as possible, while Wild (2018) states that good forecasting, based on reliable information, should be accurate and lead to low stock. Efficient forecasting for the coming demand is conclusive for its inventory management. But the future demand is consistent with a wide range of different factors, which makes it a challenging task. If the demand gets increased, the monetary savings could be achieved as well as bigger competitiveness and customer satisfaction. Destitute forecasting could result in either an understock or overstock that directly affects the profitability (Bala, 2012).

2.1.2 Inventory

Inventories can contribute to unnecessary work and decreased customer service. This can be managed with inventory management, as the stock and cost can be decreased which gives the opportunity for improved customer service (Lengu, Syntetos and Babai, 2014). Michna and Nielsen (2018) describe the bullwhip effect to be one of the main reasons for ineffective inventory management. It is caused because of uncertain demand, shortened lead times, supply shortage, the size of order quantity and price fluctuation. To be able to reduce the bullwhip effect, the causing factors need to be identified and their impacts need to be quantified (ibid).

Bala (2012) discusses the complication of inventory level caused by forecasting the demand and supports that it is necessary to integrate the supply chain management system with the forecasting system. Lengu, Syntetos and Babai (2014) highlight this integration but extend it to the product development, production and supply chain planning. Before each purchase, the customer demand needs to be considered to avoid building unnecessary stock (Bala, 2012). Sometimes, the stock

is necessary in form of spare parts, which are used for products with sporadic demand. This demand was described by Boylan and Syntetos (2008) and named as a lumpy demand. Wild (2018) mentions other reasons for the stock, such as the supply and transport failure and the unreliable or inaccurate information. The safety stock should fulfil the buffer between supply and demand and enable the company to act independently and more flexible. Lengu, Syntetos and Babai (2014) state that spare parts are associated with a substantial cost, given the inventory investments and decrease of value. Yu (2011) presents a classification technique to ease the management of inventory, where each category is managed separately with different strategies.

2.2 Classifications

There are many methods and techniques that contribute to a reduction of inventory, such as flexible manufacturing systems, visibility in the supply chain and the frequency of deliveries (Rushton, Croucher and Baker, 2010). Soylu and Akyol (2014) describe that the reason for categorising items in an order of how critical their characteristics are, is that this classification could reduce the cost for the company. For example, the inspection costs, where the company can avoid the extra cost created by unnecessary times controlling the items. The main benefit of classification is that the products are sorted based on their problems, meaning that the more important characteristics a product has, in a more critically class will this product be (ibid).

Yu (2011) states that it is an impossible task for managers to provide balanced attention for thousands of items. Wild (2018) indicates that classification is a technique used as an effective control tool. The stock itself does not provide any information about which products are more important for the company. That could be the reason why an organisation does not pay enough attention to the products that could result in a larger turnover. The technique of classification could contribute to a more optimal way of managing items on stock. Both Ng (2007) and Iqbal, Malzahn and Whitman (2017) extend the description and connect the categorisation with inventory policies that could be used based on the different groups. The later mentioned authors, develop this perspective and talk about inventory control policies contributing to an appropriate safety stock level, customer order fill rate and reorder points. Especially companies with lack of accuracy in forecasts can use this method to reduce the risk of increased inventory costs, in parallel with improving the fill rate of orders (Iqbal, Malzahn and Whitman, 2017). The Multi-Criteria Inventory Control (MCIC) aims to classify inventory items considering more than one criterion. Yu (2011) supports that a MCIC is capable to provide the accurate classification and

manage a big quantity of inventory items. According to Rushton, Croucher and Baker (2010) warehouses apply through their supply chain many different types of classification; by the material, by the geographical area, by the product type, by the function or by the ownership.

2.2.1 Single criterion

To handle all the available SKU the company needs to have an accurate control and deal efficiently with the inventory management, no matter its size. To manage their inventory efficiently, organisations use an ABC classification, to match each product category with the most optimal strategy (Iqbal, Malzahn and Whitman, 2017).

Pareto analysis, could be described as a decision making tool where improvement impacts could be provided even by small number of contributory factors (Harvey and Sotardi, 2018). According to Wild (2018), could be used in two different ways. The first way is long-term inventory management and it is based on turnover, while the second one is based on current stock and is about providing solutions for the current stock level. Inspired from Pareto philosophy, ABC classification method was established to control and manage inventory stock (Flores and Whybark, 1987). According to Wild (2018), the ABC analysis is a simple tool that creates control over a large number of products in a limited period of time. This approach reduces the stock value as non-profitable items are stocked, as well as decreases the workforce, as they can work more efficiently. A single criterion method is, according to Iqbal, Malzahn and Whitman (2017), the easiest approach to use, as only one criterion is taken in mind for categorisation.

ABC classification divides the items into three different categories and analyses them separately, which gives the opportunity to manage them differently in order to optimise their strategies. These categories named A, B, and C, and are based on annual dollar usage per item (Yu, 2011). According to Soylu and Akyol (2014), the three categories are classified in this way based on the level of importance they have for the company. A-category is classified as the most important products, B the important products, and C the less important products. The categorisation of the items is based on a singular criterion, such as the value times annual usage used in Pareto's example. The singular criterion analysis could result in misleading outcomes since other criteria could also be of value (Flores and Whybark, 1987). It is significant for companies with inventory to classify these groups to increase the control and develop the efficiency (Millstein, Yang and Li, 2014). Wild (2018) proposes that A-class products should be controlled more tightly since they are not too many, the system should manage the B-class products since they are more and

not so important, whereas there is no rational reason to take a risk for C-class products since they are not of excessive inventory even though they are of high amount.

2.2.2 Multi-Criteria Inventory Control

The use of MCIC techniques expands the opportunity to improve the efficiency of inventory management. Scholz-Reiter, Heger and Meinecke (2012) describe MCIC to connect the inventory classification with other criteria, for example, different levels of fluctuations in consumption. Iqbal, Malzahn and Whitman (2017) discuss the inventory classification based on the purpose of it, for example, if the aim is to improve the customer order fill rate then the classification should be orientated in that direction. Using multi-criteria methods that include several criteria, could a classification increase the efficiency. That is conclusive with Bala (2012), who describes the purpose of his MCIC as a way to analyse the customers' behaviour, in order to create customer profiles. On the other hand, Soylu and Akyol (2014) support that each industry and company have its own preferences on criteria and different weights depending on the characteristics of the branch. This could be a critical part as the methodology needs to be adapted, and thereby also the problem's parameters for the decision makers' knowledge and experience. Authors agree that other characteristics of the inventory may affect and change the categorisation of the items classified based on the traditional method (Flores and Whybark, 1987; Ramanathan, 2006; Ng, 2007; Yu, 2011). This creates the need of including other characteristics in a multi-criteria method.

There are several different perspectives and approaches included in a multi-criteria method, each one having its own different requirements. The cross-tabulation matrix method was first presented by Flores and Whybark (1987) where several criteria were included. The method gets complicated if three or more criteria are combined. The clustering technique described by Cohen and Ernst (1988) requires a big amount of inventory data, where each item results in new factor analysis and which demands the model to be repeatable. The analytical hierarchy process presented by Partovi and Burton (1992) includes both quality and quantity aspects in their criteria but requires a subjective opinion from a decision maker. Park Bae and Bae (2014) separate the models into data envelopment analysis (DEA) methods, which deal with several criteria in inventory classification in an eased way, regardless of the limited effectivity. In the DEA approaches the criteria and their weights generate normalised scores, also called as inventory scores. Ng (2007) describes the DEA linear optimisation methods to exclude subjectivity.

The Ng-model is described by Ng (2007) to be based on calculating scores using a traditional ABC philosophy without obtaining scores from a linear optimisation programming. The method, as explained in sub-chapter 2.4, proceed to first transform the measures to a scale score for inventory items, and then classify them by simple calculations. Yu (2011) describes the method to exclude subjectivity and optimise the inventory score. He continues by mentioning that most common limitation is that the model needs to be updated each time a new inventory item is introduced. Ng (2007) states that the model should have a limited number of criteria since large quantities of criteria could add pressure on the decision maker. It is of great importance that Ng (2007) emphasise that this formula includes and compares the extreme values of the criteria. For this reason, the decision makers should be careful when including these values since they would probably not indicate the real or normal situation. Iqbal, Malzhan and Whitman (2017) state the annual dollar usage to be the most important criterion in Ng-model, as the items with the highest value on these often receive a higher classification.

2.2.2.1 Linear and optimisation

According to Behera and Chakraverty (2014), linear equations, despite their complexity, are of great importance in everyday problems connected with optimisation, current flow, and engineering. The equation can be expressed as a YZ=X equation, where the Y and X are standard complex matrices and Z the unknown complex vector. These parameters in the real life can be complex and unclear, which are outcomes of the uncertainty or lack of experience. Ansari and Rahman (2011) point that usually a linear equation is time-consuming since the process can be characterised as a repeating process. The authors propose as a solution to this problem the analogue computers which copy and imitate the model of neurons, named as Artificial Neural Networks.

A multi-criteria method is further developed to be either optimisation techniques or non-optimisation techniques (Iqbal, Malzahn and Whitman, 2017). Park, Bae, and Bae (2014) explain that an optimisation model provides a more sophisticated classification of the items. Ramanathan (2006) describes the optimisation to be used when the weights are chosen, to constraint the weighted sum, measuring the same set of weights.

2.3 Criteria

Different criteria can affect the classification of an item and therefore can the traditional analysis be inefficient for a company (Flores and Whybark, 1987; Ramanathan, 2006, see Hatefi, Torabi and Bagheri, 2013). Xiao, Zhang and Kaku (2011) support that the criteria play a significant role during the evaluation, is the importance of the items. Hatefi, Torabi and Bagheri (2013) divide the criteria into qualitative and quantitative ones. Criteria that can be placed into numerical values are these that could be considered as quantitative, compared to qualitative criteria that cannot be expressed in this form.

2.3.1 Demand

Bandyopadhyay (2015) states that the annual usage is the same as an item's demand during a year. Hatefi, Torabi and Bagheri (2013) describe the annual dollar usage to be the most common classification for the traditional ABC classification. Flores, Olson and Dorai (1992) are critical to the usage of only annual dollar usage as it can exaggerate the importance of the items with higher annual cost and does not have an important role for the production operation for the company. This can therefore result in an inefficient management of the inventory assets. The ABC classification is also stated to be useful and powerful as it provides guidance for the management to focus on the products with the highest payoff (ibid). Iqbal, Malzahn and Whitman (2017) state that the level of demand is conclusive on which category an item will be classified. Therefore, a change in demand could impact the classification of items.

2.3.2 Lead time

The lead time is one of the most important parts of the supply chain since it affects the company's success and profits (Rushton, Croucher and Baker, 2010). The definition of lead time often includes several steps as order preparation, order transit, supplier lead time, delivery time and the setup time (Tersine, 1982; see Panda, Rong and Maiti, 2014). In a perfect scenario, the customer would wait for the requested number of products despite the lead time. In this situation, the need of the stock would be eliminated and the customer demand would be optimally satisfied when the product would be delivered. In some situations, it takes a lot of time and effort for a company to deliver or to manufacture the final product, which increases the lead time and increases the inventory. It is the lead time gap, which is explained as the correlation of the logistics lead time and the customer order cycle time, that defines the amount held in the inventory (Rushton, Croucher and Baker, 2010).

Rushton, Croucher and Baker (2010) mention that additional safety stock affects in a positive way the lead times since the products are easily available when they are demanded. Wild (2018) purposes that the inventory stock could be reduced if the lead time would be shorter but only in a minimum amount since the improving forecasting or planning impacts the result in a bigger extent. The only situation that the shorter lead time could have a greater effect in the stock is either if the demand is lumpy or if the supply time is shorter than the demand lead time. If the lead time is known, the transportation cost and the purchasing cost could be optimised, which will result in reduced stock value (ibid).

2.3.3 Supply price

Shen, Chen and Xiao (2011) divide the all-in cost for product into three parts; the quality cost, the delivery cost and the supply price. Huang, Menezes and Kim (2011) separate the supply price from the transportation price, even though it is usual that the purchasing price includes the transportation price. Zhang, Shang and Li (2011) explain that a small change in the supply price could make a bigger impact on cost savings comparing to improved forecasting of demand uncertainty. Flores, Olson and Dorai (1992) describe that companies with high holding value on obsolete products may create financial losses but depending on the sector this could be of an interest. For example, in the health sector, the constant existence of an inventory is of great importance no matter the financial cost since that secures human lives.

2.4 The process of the Ng-model

To formulate this model, the authors of the report inspired by the multi-criteria model and more specific the Ng-model, developed a weighted linear optimisation model which could satisfy the case company's demand, lead time and supply price. Although the model is based on linear optimisation, the linear programming is not needed in the simplified version, as the transformation formula fulfil the purpose of the linear optimisation. The most used criteria are the cost of items, the annual dollar usage and the lead time (Iqbal, Malzahn and Whitman, 2017).

When the demand changes, it is necessary for the company to support this shift appropriately. The criteria need to be decided based on their importance for the organisation. Criterion one is the most important and criterion three the least. This depends on the company and its targets. For instance, if the focus is to fulfil customer demand rather than keeping the inventory low, will the

criterion of the annual requirement be more important than lead time (Iqbal, Malzahn and Whitman, 2017).

Based on this information Ng (2007) explains the steps to be;

1. Gathering specific data based on the model's criteria. Organise the information in order to ease the upcoming steps.
2. Decide upon the weight for each criterion and rank them between 1-3.
3. Transform the data into a comparable value between the numbers 0, 0.1, 0.2, …, 1.
4. Calculate the sum of scores of each item under each criterion.
5. Sort and rank the items after their total sum.
6. Categorise them according to the ABC analysis.

These steps will result in a classification and a ranking of the items. Further analysis of the steps and how they work can be found in the Appendix 1.

3. Methodology

This chapter will present the thesis approaches and methods used by the authors to collect the appropriate information and proceed with answering the research question. The research approaches, the research design, the research method, the research analysis and the research quality of the thesis were defined. Moreover, the chapter examine the thesis' validity, generalisability and critical review of the study´s limitation.

3.1 Research Approach

Guba and Lincoln (1994) distinguish different types of paradigm, which are used as a system of the worldview of the existing data. The paradigm for this research has been an interpretivist one, as described by Collis and Hussey (2014), and used to analyse the complications of social phenomena, for instance to better understand the reason why something happened. Interpretivist approach is also described by Blumberg, Cooper and Schindler (2011) as a way used by the researchers to acquire a more in-depth knowledge and understanding of various phenomena. This research approach was chosen to be the most suitable for this case study. Since the authors found

the studied area quite unresearched, they tried to connect the model with a case study company to test a concrete example. Bryman and Bell (2011) support that the researcher's subjective experiences and personal opinions upon these phenomena could be included in the interpretivism method. The authors, after being critical to the actual application of their view into the real world and understanding how diversify factors could influence their point of view, realise that they could affect the whole outcome of the research. In interpretivism, the authors try to understand in depth the diversify social actions instead of relying on external forces. This is important for the research questions as an investigation of ways to improve the strategy is in focus.

Walsham (1995) proposes three different examples of ways to use the theory; as a guidance to design and gather the appropriate data based on previous theory, as a repetitive process of collecting and simultaneously analysing data connected with a case study example, and as a way to perceive theory as an outcome of a case study. Later, Mingers (2012) separate the processes of collecting theory in deduction, abduction and induction methods. In the abductive method, the authors are trying to study facts in order to explain a hypothesis. It often starts with a case whereby the researcher founds a theory which explains why the situation occurs. This research combined these theories and followed an abduction approach and a repetitive process to balance the empirical information with theory. Throughout the writing process, the authors have mixed information between theory and empirical in order to better understand the situation. This method has also helped the authors of this thesis to better understand which theory need more focus, and which area of the study could be included.

3.1.1 Qualitative approach

The qualitative method can be used with any research paradigm, which makes questions about the paradigm more important than the questions about the method (Guba and Lincoln, 1994). The authors define qualitative research as multimethod research which focuses on explaining phenomena and meanings. Blumberg, Cooper and Schindler (2011) propose different empirical material used to accomplish this method, such as the interviews, the observation, the optical and acoustic data, the case studies, the psychological tests, the document analysis, etcetera. In this thesis research, the authors used the interviews, websites and observations material in order to conduct the qualitative data collection.

Collis and Hussey (2014) mention that researchers basically prefer the qualitative data analysis method when there is no actual intention to analyse qualitative data statistically, and therefore

there is no reason to quantify the qualitative data. Using the qualitative method of collecting data, researchers tend to gather data rich in details and depth. This has been the main focus in the study, as it was necessary to early understand the current situation. The literature mentions that there are 10 different steps to conduct a qualitative research (Chenail, 2011), inspiring the authors of this thesis to the followed procedure of the study. The authors first reflected on what interested them, which was the problem solving, then they identified the preliminary area of interest, which was the warehouse management, and justified the practical importance. The topic focus was decided based on the questions “who?”, “what?”, “when?”, “where?”, “why?” and “how?”. Next, the authors' initial research questions were composed, and the authors' goals and objectives were defined, which where to identify what was necessarily to implement a multi-criteria inventory method. As this was an abductive research was the mapping of the existing situation priored before the authors conduct a detailed literature review and developed their research design. To deal with the excessive level of commitment, the authors had to understand their personal strengths and develop some skills they lack. Last, the authors planned and managed the study, and finally, when the study was written and composed, they submit the final report.

3.1.2 Quantitative approach

Bryant and Peck (2007) describe the quantitative research to collect and analyse data in terms of quantity, intensity and frequency. It often analysis a relationship between variables and not the processes, as the qualitative research fulfil. Collis and Hussey (2014) refer that either the researches quantify the already gathered qualitative data in order to analyse them in statistical ways by counting the frequency of occurrence of some terms and keywords, or they chose to gather directly statistical data. The quantitative approach could for some researchers appear to be harder, because of the required knowledge of analysing statistics. In this thesis, the quantitative part was used in the pilot study as the model should be tested. To support even more the findings, to better understand if the chosen variables are the right ones, but also to see if the result somehow visualises the reality, an additional preliminary test was conducted. Therefore, the quantitative part in this report was complement the findings in the qualitative research and answering the first research question, as it directly resulted in the requirements to implement a more sophisticated method.

Before collecting any data, it was necessary for the authors of this thesis to acquire some skills on the software where the data were available. QlikView is a software that provides a self-service about the business organisation and it eases the process of analysing data which can contribute

to an easier decision process (QlikTech International AB, 2019). Information and data were also collected from the SAP software, with the purpose to complement them with the information collected from QlikView. As the authors had limited knowledge about the software and how the case study company handle them, the QlikView software was primarily used, as the tool was easier to manage comparing to the SAP.

Based on Collis and Hussey (2014) and Bryman and Bell (2011), eight steps were followed in this thesis to conduct a quantitative study, which were further supported by a pilot study. First, the authors identified some variables based on the literature review previously conducted, which was the annual dollar usage, the unit cost and the lead time in this specific order. Then, the appropriate data were collected by the authors and a preliminary test was conducted. During the preliminary test, it became out of the authors' consideration that the variables should change, since for the case study company the most important variables were the demand, the lead time and the supply price in that order. The authors had to adapt the method after these findings and select a randomly a sample. The research data were collected from the appropriate software and later they were analysed by the authors. The next step was to develop findings based on the collected data and lastly to write conclusions.

3.2 Research design

The process that this thesis has been based on is the case study methodology, as described by Collis and Hussey (2014). According to them, a research can consist of several types of case studies. They divide these types into descriptive (characteristics of the current practice), illustrative (presented innovative practices for the company), experimental (examine difficulties in implementation of the new proposals) and explanatory case study (used existing theory to develop knowledge about the situation). In this study descriptive, illustrative and explanatory types of case studies were combined, as the descriptive was used in the current situation analysis, illustrative through the pilot study and explanatory in the preliminary test. Bryman and Bell (2011) divide the case study into four types based on the subject studied; the single organisation, the single location, the person and the single event. In this report, the authors research a single location case study since they investigate a specific company's operations and warehouse management to support their research. The evidence used in the case study could derive out of six sources according to Yin (1989); the reports, the records, the interviews, the direct observations, the participant observations, and the data.

Case study methodology has resulted in advantages and disadvantages, where one of the basic benefits has been the deriving acquisition of a full picture of the company and the in-depth understanding of its needs. The basic disadvantage, though, had been the great amount of time invested in order to create value for the researchers and the company. According to Walsham (1995), the differentiation in the period of time a research is conducted could influence the behaviour of the observed subject. The methodological triangulation has also been used as more than one sub-method have been used to collect and analyse data (Collis and Hussey, 2014).

3.3 Research method

Collis and Hussey (2014) describe primary data to be field notes and observations and secondary data to be articles and reports. This study combined both primary and secondary data, which will be presented in this chapter. The thesis required research data from the company's internal system as well as general interviews and observations from people, which added value to the research process. By analysing the data and the current situation in the case study company, the disadvantages of existing measured processes could be identified. The interviews' and observations' purpose were to create a current situation analysis for the authors of this thesis to understand the existing strategy, as well as to increase the knowledge of the ways a future strategy could follow to improve the classification with more relevant criteria.

3.3.1 Observations

Observation is described to picture situations, with the purpose for researchers to understand the sample behaviour (Marshall and Rossman, 1989). Observations happen under natural circumstances so that the researchers can learn about the activities (DeWalt and DeWalt, 2002). Schensul, Schensul and LeCompte (1999) are relying on the earlier definition but add, that the observations result in an insight of the day-to-day or routine activities. The authors observed the everyday meetings between the logistics managers to create an understanding about the company routines and how they managed critical situations.

DeWalt and DeWalt (2002) say that the benefit of observations is that it creates an integrated understanding of a phenomenon. The authors of this thesis tried to understand the insight of the company's process by observing operations such as the warehouse, facilities, and warehouse management. Bernard (1994) supports that the observations make it possible to collect different

types of data, as well as help the researchers to develop further questions. It creates a possibility to understand the culture and soft data, as well as quantitative data.

The research environment of the authors was a natural setting where the researches could go and see the factors which influence the studied phenomenon. It was of the authors possibility to visit both the physical warehouse and the office area. According to Collis and Hussey (2014), the natural everyday setting is more suitable in a study designed under the interpretive paradigm, which applies to this research design. There are two different types of observations named by Collis and Hussey (2014) as non-participant observation and participant observation. In this case study, the participant type of observation has been used, as all the participants were fully informed that they were observed. The authors of this thesis used this method since their initial goal was to access as much information as possible and reach a deeper understanding of the current situation and the processes.

3.3.2 Interview

According to Donalek (2005), an interview could be considered as one of the most widely used method to collect qualitative data. Interviews could be complex since they are closely connected with the communication of different people and the analysis of people behaviour. The sample for the interviews was the employees of purchasing and planning as well as the people connected with the warehouse. Bryman and Bell (2011) describe interviews in qualitative research to be more general comparing to quantitative research since the target is to collect the interviewees' own perspectives and formulate patterns. The interviews were conducted based on interviewees' own opinion and not on researchers concerns, and for this reason the process of the interview was not structured but it was based on the participants' communication and the way the interviewer frames the issue. The researcher could modify the order of the questions, or their content by deleting or adding new, based on the interviewees' replies. The main goal was to reach detailed information by receiving detailed answers. For this reason, an interviewee could be interviewed more than one times (Bryman and Bell, 2011).

According to Bryman and Bell (2011), there are two main categories of qualitative interviews; the unstructured and the semi-structured. In this research, the type of interviews conducted were the unstructured interviews. The authors had only abstract topics of interest before attending the interview occasion, which resulted in limited prepared question. The interviewees could speak openly about the discussed topic, which targeting in bringing even more depth into the answers.

As the questions were quite few and open, the interview turned into a conversation, which the interviewees could guide themselves and focus on the most important themes for them. Example questions can be found in Appendix 2. According to Collis and Hussey (2014), an unstructured interview could be time consuming since it is hard to control the range of topics and to analyse all the provided data. Nevertheless, the authors of this thesis decided to devote the time needed, hoping for an in details and in-depth understanding of the current situation in the case study company. Doody and Noonan (2013) support that the interviews are not lacking entirely of structure since the absence of a structure could lead to the collection of unnecessary information. In fact, during the unstructured interviews, the authors of this thesis were familiar with the topics they wanted to cover based on the explored area and became flexible.

Interviews, both scheduled and unscheduled, might not always directly added information to the thesis outcome. Nevertheless, these meetings still added value by filling up the knowledge gap existing and make it easier for the authors to draw conclusions. Based on the knowledge the authors acquired, they were later able to connect it with a suitable model. This insight in the company gave the authors guidance and eased the process, as questions could be asked to appropriate people direct and suitable theory could be connected.

3.3.3 Preliminary Test and Pilot Study

The Oxford University dictionary (2019) and the Cambridge dictionary (2019) define the noun preliminary to be a discussion happening before the actual implementation of an action. The authors of this thesis used this noun and described it as an adjective, “preliminary test”, which is an argument that occurs before the introduction of the model. The preliminary test consisted of a meeting where the authors prepared a presentation of the Ng-model and tried real products to investigate if the outcome confirmed the opinions of the purchasers. During this test, possible dilemmas were investigated and other thoughts about the Ng-model were discussed.

Pilot study, according to Given (2008), is a way to implement or test in a small extent the research. It is often connected to quantitative studies and should have a clear purpose stated before execution. A pilot study is described to be, by Blumberg, Cooper and Schindler (2011), the application of the model in order to find weaknesses or errors in the design. During the pilot study process, the researchers can double check various reasons which could affect the final test. At this point, the researchers could revise the text in order to comply with the laboratory or environmental conditions (ibid). The authors of the thesis created a pilot study based on the

model, with the purpose to analyse the model and identify if it provides a reliable outcome. With real numbers from the company's system the authors tested the model, which is more detailed explained in chapter 4.5.

3.4 Research Analysis

As this thesis consists of both qualitative and quantitative methods, different approaches had been used to analyse the result. Analysing the qualitative methods, for example, could be coding and content analysis (Collis and Hussey, 2014). The general analytical procedure (Miles and Huberman, 1994) had been used in this research, and it is stated to leave a lot of space in the process of data collection and analysis. The method consisted of three parallel flows of reducing, displaying and drawing conclusions between data. By deciding about continuous limitations among the process, it was easier to reduce unnecessary data and keep a clearer focus. Miles and Huberman (1994) also describe the process of data reduction, where information got selected, focused, simplified, abstracted and transformed into a text. Collis and Hussey (2014) describe the biggest issue of managing qualitative data to be the identification of richness and the depth in the collected data. The reduction process is of an importance to maintaining the recognition of high-quality data that are of relevance for the result. The reduction process could be done by reducing the number of interviews or observations, but it increases the risk of missing important information, which is an important trade-off for the researchers (ibid).

Having conducted the observations and interviews, the authors of this thesis decided to continue with the collection and the analysis of the reachable data. The approach of analysing the quantitative statistics had been a spreadsheet in the programme Microsoft excel, whereby the formula had been used in order to sort and calculate the result. This method had been actively chosen by the authors as they wanted the reliability to be high in this study. In order to easier answer the research questions, this method was advantageous. Collis and Hussey (2014) describe statistics to be in descriptive form, summarising the data in tables and charts, which came to be relevant for the presentation for this study.

3.5 Research Quality

Research quality is characterised by reaching more in-depth and detailed data (Collis and Hussey, 2014). The quality of the provided to a research data could affect the result of the whole study. An additional factor impacting the research quality is the human aspect taken into consideration

during data analysis (ibid). At the qualitative research, it is usual that the researchers' personal opinion and beliefs impact and bias the outcome (Bryman and Bell, 2011). Instead of reducing them, the authors in this specific thesis tried to identify and analyse them to see how they could affect the collection of data. It is of the authors' consideration that since participant observations were conducted, the participants could change their behaviour due the presence of the researchers and answer what they think based on what the company wants them to say or what the researchers expected to hear. It is very common that the outcomes of this kind of observations could mislead the result. DeWalt and DeWalt (2002) state that the limitation of using observations is that the researcher's gender, ethnicity and class, could affect the observations and therefore directly the outcome of the study.

The quantitative study could as the qualitative be affected by the researchers. Depending on how well the authors knew what they wanted to study, outcomes of the qualitative data could be related to the quantitative research and the analysis of the statistics. With an unclear purpose, it could be hard for the researchers to find appropriate statistics that match the already founded qualitative data. In addition, in this specific research, the authors level of knowledge in analysing data and the math included in the model could affect the outcome. Collis and Hussey (2014) support that many authors avoid the use and analysis of the statistics due to this reason. A possible misplacement of information could affect the quality of this research, as the researcher could believe that they have all the necessary information even though this may not be the case.

3.5.1 Reliability

Reliability is described by the author Collis and Hussey (2014) to present how precise the result of the study could be. The study needs to be able to present the same result repeatedly to consider reliable. One potential weakness of this research is that it could be complicated to repeat the study, which directly affects the reliability. Nevertheless, Leung (2015) states that a margin of diversity in the results could be accepted.

Silverman (2009) suggests five ways to increase the reliability in a study, one of these were to using triangulation, as the study becomes more comprehensive. The authors tried to add the triangulation on different parts in the research to increase the study's reliability, for example in the number of main sources in each subject and the usage of several methods of collecting data, of both qualitative and quantitative manner. Ratner (2002) explains that the researcher's bias could affect the subjectivity of a study. By using the method of triangulation this could avoidance

of subjectivity be managed. As the study used the observation method, vague statements were more elaborated and stated. Levitan, Andrew, Gilsenan, Ferguson, Noel, Coplan and Mussen (2011) state that this method increases the reliability of a study.

3.5.2 Validity

According to Collis and Hussey (2014), interpretive studies provide results with high validity. Leung (2015) describes validity to measure the appropriateness of the study, in relation to the research question, method, the design, data analysis and if the results and conclusions are valid for the context. This is consistent with the definition of validity by Bryman and Bell (2011) to deal with the accuracy of the conclusions derived from the research.

Bryman and Bell (2011) distinguish four types of validity dealing with different concepts; the measurement validity, the internal validity, the external validity and the ecological validity. This research is mainly focused on internal and external validity. According to Mora, Deakin, Reid and Angelidou (2019), internal validity is a case study applied to test the feasibility of the procedure used. In this way, some limitations are revealed, and some requirements of changes are more easily mentioned and solved. Bryman and Bell (2011) support that internal validity is mostly connected with the causality of the research, which means that its goal is to answer the question if the relationship between two or more variables states. In this research, the internal validity tries to answer the question if there is any actual connection among the criteria demand, lead time and supply price, and if these criteria are enough to manage a categorisation of the products in a company. The authors of this thesis support that there is an obvious connection among these criteria, since, according to the literature, all three of them are significant for the warehouse management. It is of the authors' concern that these three criteria are probably not enough for the categorisation of the products, but, due to the time limitation, the authors decided that these are the most important criteria and they focused the research upon them.

External validity, on the other hand, is described to test the generalisability of the research (Bryman and Bell, 2011). This means that the important factors affecting the outcome of the research are tested and tried to be combined with other similar situations. The same opinion is supported by Blumberg, Cooper and Schindler (2011), as they state that the basic concern of the external validity is to test the possible interaction between different variables and try to generalise the outcomes provided to times, settings or persons. In this research, the authors strongly believe that the study could be useful for other companies facing problems with warehouse management.

The criteria are chosen, the demand, supply price and lead time, are important factors affecting the majority of the companies nowadays.

Leung (2015) supports that one approach managing generalisability is to maintain the same criteria for validity, using triangulation and constant comparison, which occur in this study. Collis and Hussey (2014) discuss that in interpretivism studies generalisation is of interest as it can be transferred between similar situations. A study that research a pattern occurring in a situation could be applied in similar occasions. In order to fulfil this generalisation, a comprehensive and a deep understanding of the activities is required (ibid).

3.6 Research Limitations

According to Collis and Hussey (2014), the limitations in a study describe the existed weaknesses able to affect the result. One of the basic limitations the authors of this study had to face was the time. The whole research was adjust based on the fixed time frame provided, which was approximately three months. For this reason, the most important factors were taken into consideration, as well as some of the information provided was taken as granted. According to the information provided, there exist two different types of stocks; regular and spare part stock. The authors of the study decided to manage these types as one since there is no clear differentiation between them.

Even though the authors' had academic knowledge about the warehouse strategies, previous knowledge about the organisation and its systems could support further the research. Information about the company and its processes was given to the authors by the external supervisor connected with the company. The information provided to the authors was from the QlikView software and some limited data from the SAP software. The research can be further developed when more information will be available.

4. Empirical Analysis

In this chapter the case study company operation management will be presented and described with the necessary information, having as a purpose the deeper and in details understanding of

the situation at the company. First will the qualitative findings be presented and later the quantitative results.

4.1 The products

ABB Jokab Safety AB is described to deliver more than just a product to the customer and focuses primarily on the products and the functions around the usage of them, since the target is to optimise the full process rather than sub-optimise parts of it to satisfy the customer demand. As the company exists globally, the safety products differ based on culture, industry and common sense, which requires that the company is more involved in some situations. If the company wants to title a product as a safety product, there is a need of redundancy and diagnostic. The products need to be linked together, so if something can affect the safety of the process or the people manage the operation, should it be able to stop it in a safety way and not continue before it becomes 100% safe. The risk assessment is of a big importance for the company while communicating with a customer, where they need to state the safety level of each function to focus on the right purpose and real demand. The biggest customers for the company are divided into three classification, firstly original equipment manufacturer, where the movement of the equipment for machinery is highly demanded. Secondly is the robot industry for lifting and packaging and the third is the food and beverage industry.

4.2 Warehouse management

The ABB Jokab Safety AB warehouse is localised in Kungsbacka close to Gothenburg, Sweden, and was recently merged with another warehouse in Malmö. This resulted in a drastic increase in products on stock and, nowadays, the number of SKU in the company's warehouse is 775. The warehouse coordinator has a forecast on planned orders of 20 days before delivery date, and there is a natural decrease in planned orders covering future demand. The warehouse delivers directly to end customers in Sweden and Norway but also to ABB hubs in other countries. There is an existing pattern that Swedish customers expecting their deliveries the next day comparing to customers in other countries. The most common reason why an order gets delayed is described to be the lack of materials, which could be connected to a possible bullwhip effect. In this occasion, the order's arrival to the warehouse is not matched with its required delivery time to the customer.

Two types of flows exist in the warehouse, the customer orders and the stock orders. The size for products in the stock order flows is described to often be smaller items, comparing to the customer orders. Customer orders are described to be special material, whereby the stock orders do not require any management from the warehouse.

There is no inbound material delivery schedule, which contribute to an uneven entering flow during the day. The purchasers create an excel file consist of the next two days incoming materials, in order to prepare the warehouse workers on the planned loads. Each order can consist of several lines, which result in that the warehouse workers do not know the quantity before they analyse the order more carefully. Each line is one type of an item independent to the number of it. Previously, the warehouse was not categorised or sorted in somehow, which meant that the warehouse personnel needed to remember where all the products were placed. Recent projects, held by the warehouse coordinator, place the products in a decent order. The employees are informed about this placement of the products, aiming to and ease warehouse management.

During the everyday meetings, the managers analyse the most important issues of the day and the status of critical deliveries so that the warehouse know what to prioritise. The warehouse is today considered by the employees to have a high value on material stock combined with low turnover. During some time periods, the warehouse workers are ready to pack orders before the planned delivery, because of overcapacity of the products, which affects the balance of the workforce.

4.3 Purchasing process

The purchasers are working in the SAP software to manage the procurement process. Different purchasers have responsibility for particular suppliers, which means that they divide up the liability. Each month the logistics manager sends out a request to every country´s manager asking for the forecast demand to investigate in the future demand. With these forecasts can the purchaser be prepared for upcoming demand. The disadvantage of this forecast is described to be that it often is unspecific and therefore, not contributing to any value.

4.3.1 Ordering process

Each product is registered in SAP with its own item number. The software reacts to the minimum order quantity of products on stock and tells the responsible purchaser that they need to create an

order. This minimum quantity should take in mind the suppliers' variation of the lead time. When the purchasers are finished with the orders, they receive an order of confirmation, where they can note the delivery date, and inform the warehouse.

4.3.2 Stock management

In SAP each product has its own minimum quantity, which is decided when the product is new and added into the system. In some scenarios, when there is a mismatch between the received material from the supplier and the time needed to be delivered to a customer, some products might not even have the time to be placed on the stock as they are used directly to cover the delayed delivery. In some occasions when the suppliers need to produce based on the customer, the company has to order a minimum quantity of products. This means that ABB Jokab Safety AB receives more than what is ordered because of the supplier's requirements, which creates stock in the warehouse. As some products fulfil the demand at one customer, with a long lead time, do they result in a higher stock and an increased stock value.

The stock on products is decided based on a forecast provided by the product management and an analysis based on the expected demand, lead time and the reliability of the suppliers. The forecast does not include how they should manage the expected stock. Overall, a large part of the product is ordered to secure the stock level. Since ABB Jokab Safety AB does not provide any repairment services, the broken products are replaced by new ones when it is requested. The replacement of the old products satisfies mainly cost aspects and usually lead to an increase in the stock. For instance, if the company is not able to meet the delivery time in an efficient way, this would result in an increased stock. The disadvantage of not meeting the whole customer demand when it is requested is that the order could stop if one part of the line is missing.

4.4 Classification

As mentioned before, different departments use different classifications depending on the purpose and division. For example, the purchasers categorise the suppliers based on how important their products are for the processes. In this subchapter will the two most important classifications for this report be described further.

4.4.1 ABC classification

The ABC classification used today is connected with the number of times the products need to be inventoried. This classification is something that does not consider any department except the warehouse. As shown below is the most frequent inventoried products the items classified as D and E, because of a continuous gap between the amount indicated in SAP and the real quantity. If SAP shows another amount comparing to reality, the purchasing team changes it into the right amount.

The current classification is;
A= Inventoried once per quarter
B= Inventoried once every half a year
C= Inventoried once per year
D= Inventoried once per month
E= Inventoried once per month, following up because of problematic issues.

4.4.2 Product life cycle management

ABB Jokab Safety AB's products can go through four different phases; active, classic, limited and obsolete. Each product should, according to the guidelines, go through all these steps from the beginning to the end. New products enter the active phase when they become available on the market and they are ready to be sold to the customers. When a product moves from the active phase to the classic, the "phasing out" process starts, which includes the remaining steps after active. One reason why the "phasing out" exist could be that the suppliers remove some parts that is necessarily for the product or decrease in customer demand. Two times per year, in January and July, the ABB Jokab Safety AB announces which products will change phase during the next six months. This information is useful for the customer and sales department since they have to prepare the customers about the upcoming change and try to satisfy their demand.

4.5 Preliminary test and Pilot study

In the preliminary test, the authors together with the purchasers discussed the model and the limitations. The discussion resulted in increased understanding of the purchaser's workload and some changes in the criteria ranking. It was obvious that the most important criterion was the demand, which directly affects the company's profits and needs to be fulfilled in order to manage the primary operations of the company. Based on the current situation analysis, the second most

important criterion for the items was the supply price, as the purpose of this thesis was to decrease the stock value. But after the discussion conducted during the preliminary test, this ranking was later questioned and modified to be the lead time in the second place following the demand. To get the demand satisfied, the products need to be available and therefore is the lead time more important than the supply price.

The authors of this thesis decided to conduct a pilot study to manage the categorisation of the criteria and reach the Ng-model. The initial goal was to analyse the model, interpret the validity and reliability of the results. This could also help the authors to understand the possible reasons that could prevent the formula from working and the possible weaknesses that could occur. The outcome of the previous conducted preliminary test helped the authors of this thesis to proceed with more accurate results to the pilot study, improve their knowledge and draw reliable conclusions. In the pilot study, only data from 2018 are used. All the information that is required to do a classification can be founded in the case company´s system today. But as it is in different forms and on different places a solid classification is hard to be made. For ABB Jokab Safety AB to use the presented Ng-model, it is necessary for them to collect the information that is required for the model.

In order to conclude with the results of this research, the authors created a pilot study where all the information from the qualitative findings and the preliminary test were combined and included. The initial goal was for the authors to understand the possible weaknesses and to see in real life numbers how the Ng-model works. Ng (2007) claims that the model includes and compares the extreme values of each criterion. These could give the perception that the highest number in relation to the other chosen numbers, is bigger than what it is for real. Ng (2007) explains that the extreme values should be considered, but with carefulness as mislead the conclusions of a normal situation. In order to manage this problem and to exemplify the model a limited number of products was randomly chosen, where the ten highest and ten lowest values in each criterion were excluded from the sample.

Based on mentioned limitations the authors ended up with a population of 667 different items, whereby a sample of 10 items was chosen to conduct this pilot study. In table 1 these 10 items are presented, with the maximum and minimum values stated. The items chosen, do not have any specific characteristics or are not chosen from clusters of products, but are randomly chosen from

the company's products list. The components are excluded from this list as stated in the delimitations, as the authors do not test the formula on these.

Table 1 - *Pilot study sample, developed by the authors.*

Item number	Demand (no)	Lead time (days)	Supply Price (SEK)
1	5768	29	935,09
2	3217	15	229,56
3	3787	34	315,04
4	2086	16	74,88
5	2842	29	1062,66
6	1655	29	44,98
7	319	25	1046,73
8	18	26	5332,47
9	35	4	30,7
10	77	99	397,62
Max	5768	99	5332,47
Min	18	4	30,7

After the items have been randomly chosen, they were transformed. Based on what Ng (2007) propose, all the multiple measures were tried to be converted into a single score of an item in order to make them comparable, and for this reason, all criteria measures were perceived as

positively correlated with the importance of the items. This positive correlation between the criteria and the importance of an item indicates the final score of the item. Since in this model all criteria perceived to be positive, it is of authors obligation to transform negatively expressed criteria, by for instance taking the reciprocals or the absolute value of the numbers. In table 2 the sum of the ten products and their transformation numbers are presented.

Each item got transformed per criterion with the formula presented below. The transformation formula for demand is;

(measured demand-lowest demand) / (highest demand - lowest demand)

For example, items 1, 2 and 3;

1: (5768-18) / (5768-18) = 1

2: (3217-18) / (5768-18) = 0,5563

3: (3787-18) / (5768-18) = 0,6554

The result from this transformation shows that item number 1 has a higher demand, comparing to item 2 and item 3, whereby item 3 has a higher demand than item 2. This transformed outcome needs to take a value between zero and one. This transformation is later applied on each of the criterion per product, which makes the values comparable. The higher the number, the more important it is for the company's operations.

Table 2 - *Weight transformed values of numbers in Ng-model classification, developed by the authors.*

Item number	Demand (no)	Lead time (days)	Supply Price (SEK)	Transf. Demand	Transf. Lead Time	Transf. Supply Price
1	5768	29	935,09	**1**	0,2631	0,1705
2	3217	15	229,56	**0,5563**	0,1157	0,0375
3	3787	34	315,04	**0,6554**	0,3157	0,0536

4	2086	16	74,88	**0,3596**	0,1263	0,0083
5	2842	29	1062,66	**0,4911**	0,2631	0,1946
6	1655	29	44,98	**0,2846**	0,2631	0,0026
7	319	25	1046,73	0,0523	**0,2210**	0,1916
8	18	26	5332,47	0	0,2315	**1**
9	35	4	30,7	**0,0029**	0	0
10	77	99	397,62	0,0102	**1**	0,0692

The highlighted numbers are the highest criterion per item. So, depending on which criterion is the most important for the company's performance, will the highlighted number vary between the different criteria. At this stage, the weights are already included in the transformed numbers. The criteria are ranked based on their importance, whereby the weight is combined. This clarifies the statement that the authors do not need to include the subjective weights into consideration, or in the formula.

In table 3 each of the transformed numbers is calculated with the formula;

Sum 1 = transformed number criterion 1
Sum 2 = (transformed number criterion 1 + transformed number criterion 2) / 2
Sum 3 = (transformed number criterion 1 + transformed number criterion 2 + transformed number criterion 3) / 3

For example, item 1;

Sum 1 = 1
Sum 2 = (1+0,2631) / 2
Sum 3 = (1+0,2631+0,1705) / 3

For item 2;

Sum 1 = 0,5563

Sum 2 = (0,5563+0,1157) / 2

Sum 3 = (0,5563+0,1157+0,0375) / 3

For item 3; **Sum 1 = 0,6554**

Sum 2 = (0,6554+0,3157) / 2

Sum 3 = (0,6554+0,3157+0,0536) / 3

Table 3 - *Transformed and sorted numbers of the Ng-model classification, developed by the authors.*

Item number	Transf. Demand	Transf. Lead Time	Transf. Supply Price	Sum 1	Sum 2	Sum 3
1	1	0,2631	0,1705	**1**	0,6315	0,4779
2	0,5563	0,1157	0,0375	**0,5563**	0,3360	0,2365
3	0,6554	0,3157	0,0536	**0,6554**	0,4856	0,3416
4	0,3596	0,1263	0,0083	**0,3596**	0,2429	0,1647
5	0,4911	0,2631	0,1946	**0,4911**	0,3771	0,3161
6	0,2846	0,2631	0,0026	**0,2846**	0,2739	0,1835
7	0,0523	0,2210	0,1916	0,0523	0,1367	**0,1550**
8	0	0,2315	1	0	0,1157	**0,4105**
9	0,0029	0	0	**0,0029**	0,0014	0,0009
10	0,0102	1	0,0692	0,0102	**0,5051**	0,3598

Having fulfilled the transformation for each product and criterion, the products should further be sorted by their biggest sum and ranked based on the pareto philosophy, as shown in table 4. The maximum and the minimum values of the 10 products chosen in the classification during the previous steps were used in order to simplify the model and make it easily understandable.

In addition, Table 4 includes the application of the Ng-model on all products and the current ABC classification of all products used by the case study company. The authors decided to apply the Ng-model also on all products in order to deliver results which will be easily compared with the results from the current ABC classification followed by the company. To deliver accurate results, in all cases the same 10 products were selected.

Table 4 - *Pilot study result, developed by the authors.*

Item number	Total Sum	Ng-model classification	Ng-model classification on all products	Current ABC classification on all products!
1	1	A	B	A
3	0,6554	A	B	C
2	0,5563	B	C	B
10	0,5051	B	A	C
5	0,4911	B	B	A
8	0,4105	C	A	B
4	0,3596	C	C	C
6	0,2846	C	C	A
7	0,1550	C	B	C

9	0,0029	C	C	C

According to Farrukh, Hussain, Jahanzaib, Wasim and Aziz (2015) should the products be divided that A-products are 20 %, B-products 30 % and C-products 50%.

5. Discussion

In this chapter the empirical findings will be combined, analysed and discussed with the literature review, to understand and emphasise similarities and dissimilarities between these two parts. It will work as a foundation for coming conclusions and future recommendations. Moreover, the discussion chapter will be structured and connect to the research questions.

The discussion part of this thesis is structured based on the process needed to be followed during this movement to an alternative, more sophisticated strategy, in which the most important criteria are taken into consideration. At the same time, the authors had the ambition to answer the second research question referring to the conditions that are necessary to exist in order to implement a multi-criteria method.

To answer the first research question it was important to map and analyse the current situation in the warehouse, the purchasing process and the inventory management. The authors first checked whether the information collected was not only right but also placed and saved in an accessible place. To avoid any possible misleading outcomes and ease the warehouse management, the authors strongly believe that the information should be well placed and be readable. A potential misplacement of information complicates the work of the logistics management and in some occasions could lead to inaccurate results, as important information could be excluded. This idea is further supported by Shi, et al. (2012) who mention an advanced investigation in the information technology could lead to an increase in economic benefits and customer services. In this study, the necessary data were available. Nevertheless, the misplacement of the data resulted in a time consuming and risky process for the authors, trying to collect information from different files and software for analysis and discussion. For instance, the misplacement of the information

combined with the lack of knowledge about the company lead the authors to take all information provided for granted, as the information about lumpy demand. Even though there was an available guide about Qlikview and its function, the authors could not find information by themselves without help from employees.

Having all the necessary information accessible, the authors tried to understand and analyse the management of the warehouse and purchasing routines. Michna and Nielsen (2018) define warehouse management as an interaction between partners. ABB Jokab Safety AB delivers today directly to customers in Sweden and Norway, while it satisfies the demand of other ABB hubs worldwide. The warehouse manages about 775 different SKU´s, whereby this study is focusing on 667 of these. Faber, Koster and Smidts (2013) describe the management of large quantities in stock to be a complex task. Nevertheless, the high value on stock material combined with low turnover in the case study warehouse, might not prove a lack of knowledge in the management of a big quantity of products. This could be an outcome of an inefficient merge with the Malmö warehouse rather than a weakness in warehouse management.

The logistic structure, including the planning and control process of the company's operations, should manage future challenges, as explained by Rushton, Croucher and Baker (2010). The current purchasing planning in the company relies on the employees' gut feeling and employees experience. The lack of structure could result in decisions being taken without the knowledge about the arising consequences, or the process that should be followed to avoid problematic situations. This complicates the planning segment of the logistic structure and could result in a crossover effect, as explained by Michna and Nielsen (2018). The unstructured warehouse could be a reason why there is a necessity of frequent review of the inventory stock. The fact that the warehouse trusts the employees gut feeling and experience could lead to a misplacement of products in the wrong category. As too much subjectivity and lack of statistics is included in the process, the current situation is not correctly visualised, which result in inaccurate outcomes and misleading decisions.

Rushton, Croucher and Baker (2010) describe one of the most critical factors for a company's success to be the purchasing process. The case study company has five different purchasers in order to manage the process in an efficient way. To keep track of the incoming material the purchasing team is using the SAP software. Each item has its own minimum order quantity which is decided by the purchasers in the introduction phase of uploading an item, to secure the safety

stock. The authors believe that it is necessary for the system to be updated if the customer behaviour changes, to react in time and adapt to a new situation. The presented Ng-model classification could manage this problem by updating these numbers with a continual focusing on A-products, in order to get a better analysis of the customer's behaviour and faster adapt to changes. The authors suggest a continual focus on A-product because of the importance of these products and the large consequences of not fulfilling these demands. At the same time, the focus on A-products would not increase the workload massively for the purchasers.

The unbalanced incoming materials from the suppliers create an uneven work balance and are difficult to be optimised. This could lead to an increasing number of inventory stock since the case study company sometimes could purchase more than they need or could create a customer dissatisfaction since the demand would probably not be covered with the available items. As the company does not repair products for customers when it is necessary, the stock increases since further demand needs to be fulfilled. According to Lengu, Syntetos and Babai (2014), a bigger inventory stock contributes to higher costs and decreased customer service.

The bullwhip effect, described by Michna and Nielsen (2018), is believed by the authors to be connected with the ineffective inventory management. The company describes the warehouse to have a high cost and a low turnover. This ineffective inventory management results in uncompleted deliveries due to the lack of material and efficient strategies. Boylan and Syntetos (2008) explain that the lumpy demand increases the inventory stock in order to manage the customers need. The uncertainty in demand and the lack of forecast could be the reason why the bullwhip effect occurs in the warehouse today. The ABC classification and the future strategies that can be added on the different classifications could reduce this effect. Wild (2018) explains the safety stock to cover the time between supply and demand order point. This stock increases the flexibility for the company and their independent (ibid). Therefore, this buffer could increase unnecessarily the inventory stock when it is not demanded in a short period of time by the customers. The challenge is to match this demand, and not build stock over years. The company could use the possessed knowledge about the lead time of the suppliers to reach a desirable inventory stock level by avoiding the crossover and bullwhip effect, which overall will contribute in a more efficient way of managing the warehouse.

To analyse the current situation in the case study company, the authors tried to understand the classification followed today. The company today has at least two different classification of the

products covering different criteria; the product life cycle classification and the ABC classification. The ABC classification is based on the frequency of inventory rather than the annual dollar usage as Yu (2011) states, which the authors believe to increase the chances of misprioritised time and money. Soylu and Akyol (2013) describe that the reason for categorisation of products is to result in cost saving for the company. The outcome of categorisation could lead to strategies in the management of products and purchases, which increases the efficiency and thereby, savings in cost. During the analysis of the current situation at the case company, the authors noticed a gap in the management of products and more specifically an omission of several aspects in the purchasing strategies. The critical characteristics of customer demand, supply price or lead time are not included in the categorisation. This could result in that items or customers, which are of a bigger importance for the performance, not being prioritised or managed in a favourable way. Soylu and Akyol (2014) claims that each industry and company has its own unique characteristics and preferences. Trying to analyse these characteristics in the case study company, the authors concluded that on this occasion the most important criteria for the company are the customers demand, the lead time and the supply price, following this order.

The company does not provide balanced attention to all the products, as this is explained by Yu (2011) to be impossible. Soylu and Akyol (2014) state that a classification could clarify this attention dilemma if it is based on the items' critical characteristics. By targeting these characteristics, the company could more easily manage the products, and at the same time take benefit from handling similar products in the same way. This would lead to a classification, which is characterised by Wild (2018) to be an effective tool in managing products. The most important characteristics are not included in the current system of the case study company, and therefore the system became insufficient. The lack of a clear strategy or management of these situations occurs because of avoidance of the customer demand.

As the case study company has to satisfy two different customer demands, two groups could be created; one with requirement of short lead time, and one that does not face this problem. This characteristic increases the pressure on the company, as the management needs to be adapted after two different demands, which is not covered by the current system. These groups differ from each other and require contrasting ways of managing. As the demand is classified as the most important characteristic for the company, it should be born in mind to a bigger extent. The authors suggest that the company needs to investigate its possible lumpy demand, and further

consider different strategies to manage the demand. The different customer demands characteristics could be managed by keeping some products in stock until they are requested in order to fast meet these. This is a trade-off for the company, between meeting the demand and the cost of fulfilling the needs. If the demand diversifies in a big extent, special strategies could be required.

This case study has mainly been limited to what Mihir and Kailash (2005) describe to be small purchases, where there are a low volume and value, high variety, low technical and unexpected use. These characteristics lead to a crossover effect as this is mentioned by Michna and Nielsen (2018) to occur in the management of products. This effect is described to be the reason why the company cannot deliver a whole order at once, which directly affects the fulfillment of the customer demand. This crossover effect is also contributing to an increased inventory stock, which makes the system inefficient and costly.

Many possible techniques of warehouse management and purchasing strategies reducing the stock value could be fitted the situation at the case study company. Schonberger and Gilbert (1983) explain that there are tactics and strategic techniques to develop operational processes in order to become more efficient. One of these strategies proposed by Gunasekaran (1999) is the JIT technique, which increases the productivity. The conclusion that the case study company work with JIT techniques today could not be derived by the analysis of the current situation. According to Schonberg and Gilbert (1983), a further work with JIT techniques could develop the relationship between the company and the suppliers. An enhanced relationship with suppliers could better balance the order quantity between customers requested amount and the suppliers, which would be beneficial for the company.

To secure the efficiency in the production and the manufacturing processes, and simultaneously operate in the JIT approach, companies often work with a forecast. Rushton, Croucher and Baker (2010) describe the usage of forecast satisfying the future demand to be as precise as possible, which Wild (2018) extend, as it also helps to reduce the stock. The warehouse manager has a forecast on 20 days ahead, whereby the purchasing team has information about the demand for the coming month. As mentioned before, the lack of an accurate and fully established forecast affects the way the customer's demand is managed, as the managers cannot plan or prepare what requires flexibility in the system. As customers have different expectations on delivery, a future forecast could solve the problem of delays due to lack of materials, which is described to be the most frequent problem.

Rushton, Croucher and Baker (2010) explain that the warehouse and other departments could apply different categorisations depending on the purpose of it. As the case study company already has a classification of the life cycle of products, the suppliers and inventory, the Ng-model could mix information and hopefully improve existing classifications. The decision maker in the Ng-model decides upon the ranking of criteria (Soylu and Akyol, 2014). This directly affects the outcome of the classification since the experience and knowledge of the decision maker plays a big role in the results. For this reason, it is important that the decision maker is experienced enough to make beneficial decisions. The role requires subjectivity, which makes knowledge even more important. In the case study, the purchasers could not be the decision makers, as they are experts only on their section of products and do not have an overview of all items. If the purchasers were decision makers, there could be a scenario where the quantitative data gets ignored because of the experience, which would affect the classification in a negative way. Some products might be evaluated based on experience rather than the quantitative outcome. In this case study, to avoid this scenario, the Ng-model is proposed which excludes the subjectivity per item (Ng, 2007). The model though includes the subjectivity when the criteria are ranked, which motivates the decision maker to not favour specific items. Even though the subjectivity per criteria occurs, it cannot affect specific items, without influencing the rest.

The linear optimisation is, according to Ansari and Rahman (2011), time-consuming and hard to manage. For this reason, a non-programming linear optimisation was preferred. Although Ramanathan (2006) supports that the weights are of great importance for optimisation models, Ng-model includes the weights in order to limit the subjectivity. Yu (2011) states that the biggest limitation the Ng-model has is that it needs to be updated every time a new item is added. In this study, the formula is calculated in Microsoft Excel, which makes the model user-friendly, as it does not require any expensive or complicated programme. By using formulas for calculating, updating an item number would not add any extra work other than that the decision maker should write it into the sheet, which will lead to an automatic update of the sums and classification. Which therefore makes, the limitation that Yu (2011) state very easy to overcome. To make the chosen Ng-model work, the most important factor is the criteria which need to meet the technique in a proper way in order to get a useful result and not the programme analysing them.

The authors chose to only use quantitative criteria in the formula, even though the formula itself can calculate both qualitative and quantitative criteria. This is based on the authors wish to exclude as much subjectivity as possible in the model. Ng (2007) claims that there should be a

limited number of criteria taken into consideration since the more criteria are, the more pressure is on the decision maker. Yet the selection of the criteria in the case study is based on the authors' personal opinion and research and they could be revised and adapted if it is requested. There is a trade-off between numbers of criteria and the amount of time that the company could dedicate to rank the items. The authors believe that too many criteria could provide misleading results, since many aspects connected with each criterion should be taken into consideration. One of these aspects is the human mistake where the more the criteria are, the bigger chance it is for a human to make a ranking mistake. For this reason, the authors agree with the Ng (2007) proposal of a limited number of criteria. Moreover, although it could be hard to choose a limited number of criteria, the authors think that it would be easier in this way to find connections between the attributes of the items.

In the current situation, the experience plays an important role for the company to take conclusive decisions. This method of taking decisions is according to the authors, not an optimal one, mainly because of the unpredictable effects that come with it and the lack of continuity. If these effects are kept in mind before decisions are taken, the trade-offs between different outcomes could be decided to make the best decision for the company based on the situation. Decisions based on gut feeling could be hard to be explained to other people that are not familiar with the situation. With statistics and models explaining the decision, confidence could be built, and better collaboration could be succeeded. At the same time, the methodology and the structure of decision making should be standardised so that the entire system is not based on one person's knowledge. By spreading the risks, the company could easier manage unpredicted difficulties. The purchasing team has a broader knowledge about the products and the environment in the company compared to one single decision maker. The purchasers have with their long experience about the products in combination with the customers' and suppliers' behaviour. The team consists of five different purchasers and it is logical that they together have a wider knowledge compared to one person. The authors of the thesis thought that it would be a good idea to educate all of the members of the purchasing team to create the same level of understanding about the model and about the initial goal of it, and at the same time to acquire an in-depth knowledge about each class characteristics.

The knowledge is important for the decision manager not only in the process of deciding upon the criteria but also in ranking these criteria. This could be said to be even more important than the simple choice of the criteria since the rank of the criteria includes the weights. Ranking the

criteria would be mainly beneficial for the company as the accurate result and numbers for each item produced could be available for each employee. The preliminary study conducted to check this ranking and level of motivation, resulted in a conflict mindset from the purchasers and their workload, as a potential model could result in increased stress and would be time-consuming. This could be defensible with that the model is easy to use, and that it manages the classification automatically, and would not require an unreasonable amount of time. The outcomes of the model could, however, result in benefits, based on what the company wants to draw from it.

In this case study, the cost for the company decreases if the inventory cost is lowered, i.e. that the items do not stay in stock for too long. Wild (2018) supports that the inventory stock can be reduced if the lead time is shorter, which Gunasekaran (1999) also supports and extend that a more efficient process faster meets the customer demand. Wild (2018) says that a shorter lead time will improve the management of a lumpy demand, as a company with short lead time can quickly react to fast changes. Comparing to a forecast, a reduction of the lead time could affect in a bigger extent (Wild, 2018). This increases the importance of including the lead time in a heavier weight in the classification model for this study.

Since the purpose of this thesis was to decrease the stock value in the warehouse, the supply price was chosen to be one of the criteria in the Ng-model. As Zhang, Shang and Li (2011) discuss, a smaller change in the supply price could result in a big change in the stock value comparing to a possible improvement of forecasting. Nevertheless, the forecasting will result in better planning, which in combination with a change in the supply price will be more beneficial. Flores, Olson and Dorai (1992) explain that in some sectors it is necessary for a stock to exist, which might result in financial losses. Their opinion seems to be correlated with the current situation in the case study company, since the strategy is described to provide the products rather than ensure a lower cost, which means that it is better to have products on stock rather than meeting the demand.

From the application of the Ng-model some outcomes derived and discussed. Out of the ten products does the result shows that the six most valuable products also had the highest demand. The authors could understand that although the demand was highlighted as the most important criterion, in some products the other two criteria were the highest and, as a consequence, the most important. The result of the comparison of all products was that only two products from the Ng-model classification matched the current ABC classification the company follows. The products which are ranked as the most important according to Ng-model classification, appeared to be

classified as either B or C products in the current ABC classification. This catch the attention of the authors since they think that it is of a consideration that the two models diversify in such a big extent. It is the case that either the current ABC classification followed by the company should be questioned or the Ng-model was not correctly applied due to the lack of data and knowledge. The authors support that the current classification could be probably questioned since it is not consider the warehouse management, the inventory management or the existed rules given from the theory. Investigating the outcomes of the pilot study the authors thought that most important reason why the two classification are so different is because the gut feeling of the employees is highly trusted and their experience is not included in a classification. The authors of this thesis do not question the experience or the knowledge the employees have, but they strongly recommend them to apply them in a classification in order to make this knowledge easily tested and comparable.

As in all changes, it is important for the company to motivate the employees and keep them enthusiastic about developments. The employees are probably unwilling to change the way they currently work due the overall mindset of changes and previous development projects they have been involved in. If the implementation phase does not succeed in including the purchasing team, the model loses its purpose. The purpose of the model is to classify the products so that the purchasers could easier take a decision and manage the products in certain situations. So, without convincing the purchaser, to use the classification of products in their everyday work, the result of this thesis could be worthless. Therefore, it is important to have an open discussion about how to manage the products in a more efficient way.

The authors strongly advise the company to work together as a team with the different concerned departments, which in this case study is the leaders of the company, the decision makers, and the purchasers. The result of the implementation is shown in the pre-condition given to the different partners, whereby knowledge about the model, its possibilities, its requirements, and its objectives is basic. By extending the employees' understanding and knowledge about the model and its outcome, further ideas could be grown and advanced. If all divisions have the same ambition, conflict mindsets could be avoided. The bigger knowledge and understanding the employees have, and the more they have the feeling that they can affect the outcome, the more motivated they are to work with the project and reach all the benefits.

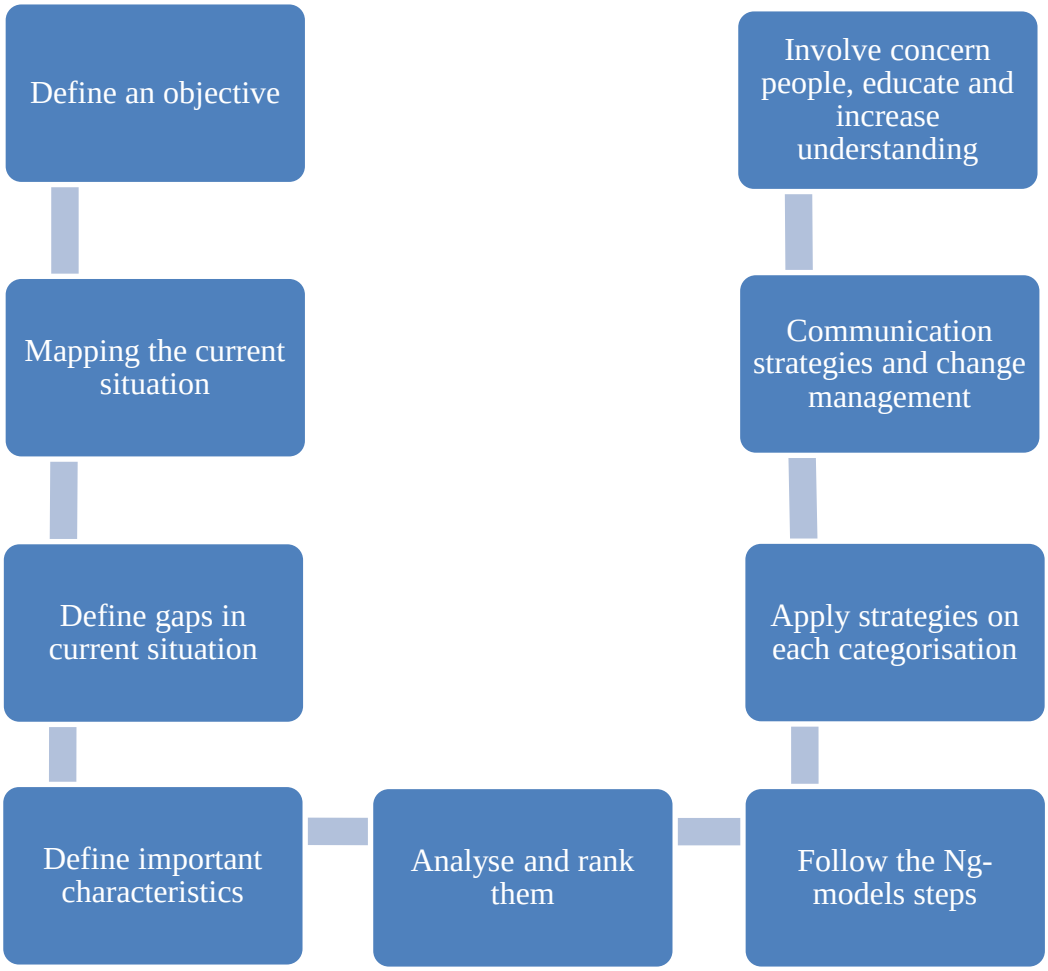
According to the authors of this thesis, many benefits could result from the use of the Ng-model. By adapting several strategies to better match the different characteristics of the classification the

stock value in the warehouse could be decreased. For example, the case study company could cooperate better with the suppliers who deliver the most important products. This could probably help them to manage unpredictable variation in demand and reduce logistics and inventory costs, which all contribute to a better economic result. The results from a classification can lead the company towards a market diversification and cooperative strategies with important suppliers. In horizontal relationship the focus should not to be on the biggest company as it could be working as a hub for other suppliers (Pérez Mesa and Galdeano Gómez, 2015). A segmentation of the suppliers alone will not affect the performance in a positive way, as energy and involvement from the company in order to get cooperation is necessary.

The classification gives the company guidance in which products, that plays a bigger role in delivery, value for the company's performance. It is important to highlight that the result of the classification does not visualise that the company should only focus on the specific class, but it gives a link between items with similar characteristics. The result from the categorisation should, therefore, be used as basic information in future strategic decision with the purpose of how they should manage a situation, in order to reduce the decision based on gut feeling.

To sum up the process steps, figure 3 below shows it visualised.

Figure 3 - Process steps, *developed by the authors*.



6. Conclusion

The last chapter will answer this thesis two research questions and explain them further in a consist way and connect this with the study's purpose. Future research and Future Recommendation are added to the thesis for further research.

To implement a developed strategy for the company ABB Jokab Safety AB, several steps are required in order to reach a successful outcome and reduce the stock value. Mapping the current situation, defining gaps in the process, analysing its impact on the company's performance and finding a proper model based on the purpose are critical. This is also the answer on the research question, "*How could a traditional warehouse strategy be moved to a more sophisticated one in*

order to reduce the stock value". The implementation would in this case study result in a decreased number of thrown away products, big monetary as well as environmentally savings on products on stock, a smoother flow of products as well as better quality of products. If more focus is put on the different types of customer demand, the company could be more flexible. By including the model into the decision taking, the gut feeling currently used in decision making could also be reduced.

Investigating the main challenges for ABB Jokab Safety AB would also answer the second research question, *"What is necessary in order to implement a multi-criteria method"*. The main challenges that the case study company needs to consider are; the different demands, and whether this should be managed in different ways, the necessity of a proper analysis on the classification, the way to apply beneficial strategies at the company, how to keep the model updated, who will decide upon routines based on the involved people opinions, and also the different ways to motivate and include people. It is important for the company and its employees to keep good communication so that more benefits can be drawn. Further competence about the items, education about the model and a spirit of working together to achieve better outcomes could help this application.

6.1 Future research

In this chapter the further future research connected to the Ng-model will be discussed and the authors' though of future development will be presented.

According to the authors of this thesis, a warehouse could be managed in different ways if the Ng-model is applied. The warehouse knowledge about real flow and behaviour of products, which are pre-demanded in the use of the Ng-model, could provide useful information about the product behaviour and real flows.

The categorisation resulted from the Ng-model classification proposed by the authors of this thesis could be used as the ground-tool to place later the items into clusters. The authors highly believe that the better the items are placed in the clusters the more the benefits will be for the company. These benefits of this placement will follow the items through all the phases of their

lifecycle, not only the active phase. As a result, problems such as the lack of strategy on the items which are placed in the classic phase could be eliminated in the future.

Furthermore, the model could be later used in combination with a forecast, which could include the clustering strategy. The Ng-model could be further developed in order to include parameters and margins that change according to the forecasting demand. Parameters named as α and β could identify these margins which would diversify the class in which a product could be ranked.

In addition, the Ng-model could be applied in companies, which rank other criteria as important based on their special characteristics and requirements. Transportation cost, quality, lead time flexibility, etcetera could be some of these criteria. The Ng-model, as a multi-criteria method, could be later adapted on other processes expect of items and warehouses, for example food industry, or directly to customers or other companies.

6.2 Future Recommendations

The chapter of the future recommendations presents ideas regarding the study's research question but also another opinion regarding alternative departments.

The warehouse today is not categorised after the operations that occur. The proposed Ng-model could lead into a more efficient and beneficial for the case study company classification. Firstly, the most important products should be located based on the different production flows so that the personnel could easily manage or pack the items. The products that are highly requested should be easily reached by a forklift in order to refill them in time and satisfy the demand. By managing the highly demanded items, the remained items will also be easily structured. Developing an efficient structure in the warehouse could result in an increase of the operations that create value for the company. The authors of the thesis recommend a theoretical research before the redesign of the warehouse since there are a lot of aspects that should be kept in mind which could decrease the cost and deliver beneficial results to the company. Nevertheless, the authors of the thesis highlight that the main focus of a change in a warehouse should be to increase the efficiency of the structure.

The authors would suggest the company to focus more on the JIT approach by fulfilling only real demands and not future ones. Focusing on the future demand affects the stock and the purchasers

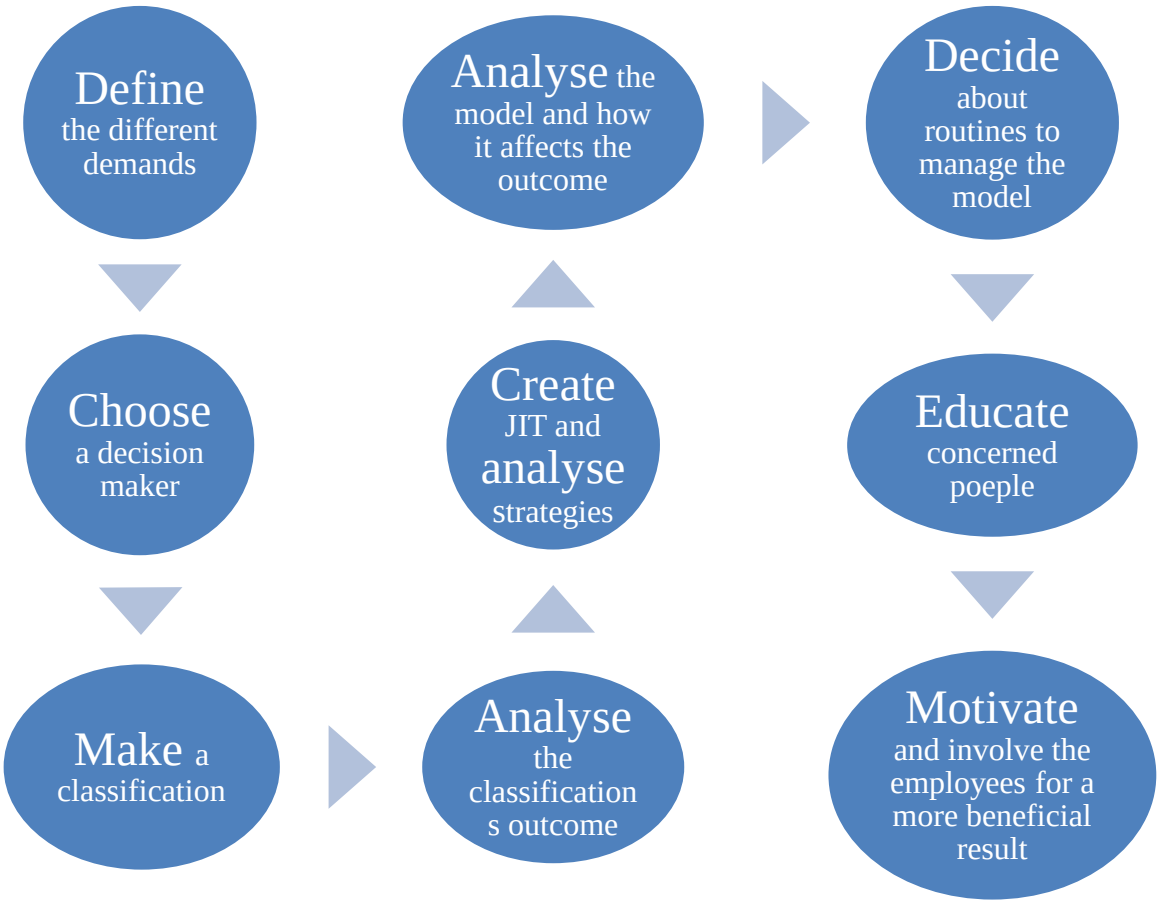
by disturbing the process. In the case of the lumpy demand, the real demand is difficult to be analysed and forecasted but trying to meet the pre-decided lead time in all orders could help the process. The crossover effect and the bullwhip effect could also be a result of orders being prepared before they are requested. The Ng-model proposed by the authors could help companies that faces the same problems to further adopt strategies that will create value for them. In cases that the demand could be forecasted, the proposed Ng-model could be extended and developed. The authors of this thesis believe that even in situations that the companies have lumpy demand, such as the one in the case study company, there could be a kind of a forecast, which could be beneficial according to Mihir and Kailash (2005). Old data saved by the company could be used and analysed by experts to predict upcoming decreases or increases in the demand. In this way, not only the inventory stock will be decreased but also the work of the purchasers and the managers will be eased. The lack of any knowledge about the fluctuations of the demand could result in great disadvantages for the company. The authors of this thesis believe that a further investigation and analysis of the customer order stock could lead to beneficial results for the company, as even if the process appear to be satisfying, misleading results might be delivered. A thoroughly investigation of the flows followed by the company could reveal these situations.

There seems to be a lack of communication between different departments about the products of different lifecycle phases and the connecting strategies. Even though there are a lot of products, there should be a statement of how a product should be managed in different stages, before releasing. For example, factors such as the future demand, the expected certification, the classification of the products, etcetera should be pre-decided to avoid unnecessary work. In this way, the company could increase the control and knowledge about future expectations of the products. Another dilemma that the company already has to face is the connection between lead time and quantity, partly between the supplier and the company, but also between the company and the customer. By negotiating with the suppliers about minimum order quantity and their lead time, the company could adapt the customer lead time depending on the ordered quantity. The company could in this way provide more realistic requirements on their own processes and meet the customer demand. This, in the end, increases the customer service. A potential solution to this problem could be the adaption of the prices to this logic and the increase of the selling prices if the supply price becomes higher. The authors of this thesis also recommend the company to pay extra the suppliers to keep the stock of the rarely requested items if their location, to decrease the stock value and the lead time. All these solutions should be based on a clustering technique

of the products. If similar products are managed in the same way, an optimal strategy could be created.

The figure below sums up the recommended steps for the case study company in order to implement a sophisticated model and thereby decrease the stock value.

Figure 4 - Future recommendations, *developed by the authors.*



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Appendix 1 Ng-Model

In the model, all the items in the inventory were named as “i” which were classified on “c” number of criteria. “yi,c” indicates the value of the inventory item “i” with respect to “c” criteria. By using the formula below will the *i*th item be transformed into a comparable value which is the basic factor for the upcoming classification.

$$(y_{ic}-\min_{i=1,2,\ldots,i(Yic)}) / (\max_{i=1,2,\ldots,i(Yic)} - \min_{i=1,2,\ldots,i\,(Yic)})$$

where $i= 1,2,3,\ldots,I$

and $c= 1,2,3,\ldots,C$

The results of this equation can be placed between 0 and 1. So,

$$0 \leq (y_{ic}-\min_{i=1,2,\ldots,i(Yic)}) / (\max_{i=1,2,\ldots,i(Yic)} - \min_{i=1,2,\ldots,i\,(Yic)}) \leq 1,$$

which indicates the possible scale of the scores given to the items.

Ng (2007) propose a formula which is later simplified and further explained. In the equation;
S= score of *i*th item
w= weight
y_{ic}=the measurement of the *i*th item under *c*th criteria

For P1, $\max Si = \sum_{c=1}^{C} w_{ic} y_{ic}$ (1)

and $0 \leq Si \leq 1$

s.t. $\sum_{c=1}^{C} w_{ic} = 1$ (2)

and $0 \leq w_{ic} \leq 1,$

indicating the normalisation constraint. No matter the number of the criteria, the total sum of the weights should be equal to 1.

To secure the sequence of the ranking of criteria,

$$w_{ic}-w_{i(c+1)} \geq 0, \quad c=1,2,3,...,(C-1) \tag{3}$$

$$w_{ic} \geq 0, \quad c= 1,2,3,..., C \tag{4}$$

Later in his article, Ng (2007) simplifies the equation to make it friendly for users and managers who do not have previous experience or high level of knowledge in mathematics. In addition, the simpler equation is easy to be solved without a linear optimizer.

So,

$$x_{ic}=w_{ic}-w_{i(c+1)}, \qquad i= 1,2,3,....,I \text{ and } c= 1,2,3,...,(C-1) \tag{5}$$

and

$$x_{ic}= w_{ic}, \qquad i= 1,2,3,...,I \tag{6}$$

From the constraints (2) and (3):

$$\sum_{c=1}^{C} cx_{ic} = 1, \qquad i= 1,2,3,....,I \tag{7}$$

and

$$x_{ic} \geq 0, \qquad i= 1,2,3,....,I \text{ and } c= 1,2,3,...,C \tag{8}$$

By expanding the (7) and substituting (5) into

$$\sum_{c=1}^{C} cx_{ic}= x_{i1}+ x_{i2}+x_{i3}+...+Cx_{iC} \tag{9}$$

$$= (w_{i1}- w_{i2})+ 2(w_{i2}- w_{i3})+ 3(w_{i3}- w_{i4})+...+C(w_{iC}) \tag{10}$$

$$=\sum_{c=1}^{C} w_{iC} \tag{11}$$

Since $\sum_{c=1}^{C} w_{ic} = 1, \quad i = 1,2,3,....,I,$

then (7) is true. In addition,

$$k_{ic} = \sum_{c=1}^{C} y_{iu} = 1, \quad i = 1,2,3,....,I \tag{12}$$

If the score Si of the item is expressed in terms of x_{ic} and k_{ic} for $c = 1,2,3,...,C$,

$$Si = \sum_{c=1}^{C} w_{ic} y_{ic} = \sum_{c=1}^{C} x_{ic} k_{ic} \tag{13}$$

From (13) by substituting (5) and (12) into (13), and then expanding the summation:

$$\sum_{c=1}^{C} x_{ic} k_{ic} = \sum_{c=1}^{C-1} ((w_{ic} - w_{i(c+1)}) \sum_{c=1}^{C} y_{iu}) + x_{ic} \sum_{c=1}^{C} y_{iu}$$

$$= ((w_{i1} - w_{i2}) y_{i1}) + ((w_{i2} - w_{i3})(y_{i1} + y_{i2})) + ((w_{i2} - w_{i3})(y_{i1} + y_{i2} + y_{i3})) + ...$$

$$+ ((w_{i(C-1)} - w_{iC})(y_{i1} + y_{i2} + ... + y_{i(C-1)})) + w_{iC}(y_{i1} + y_{i2} + ... + y_{iC})$$

$$= (w_{i1} y_{i1} - w_{i2} y_{i1}) + (w_{i2} y_{i1} + w_{i2} y_{i2} - w_{i3} y_{i1} - w_{i3} y_{i2})$$

$$+ (w_{i3} y_{i1} + w_{i3} y_{i2} + w_{i3} y_{i3} - w_{i4} y_{i1} - w_{i4} y_{i2} - w_{i4} y_{i3}) + ...$$

$$+ (w_{i(C-1)} y_{i1} + w_{i(C-1)} y_{i2} + ... + w_{i(C-1)} y_{i(C-1)} - w_{iC} y_{i1} - w_{iC} y_{i2} - ..._ w_{C4} y_{(C-1)})$$

$$+ (w_{iC} y_{i1} + w_{iC} y_{i2} + ... + w_{iC} y_{iC})$$

$$= (w_{i1} y_{i1} + w_{i2} y_{i2} + ... + w_{iC} y_{iC})$$

$$= \sum_{c=1}^{C} w_{ic} y_{ic}$$

For all items i:

$$w_{ic} = \sum_{c=1}^{C} x_{iu}, \quad c = 1,2,3,....,C$$

and since $x_{ic} \geq 0$, $c = 1,2,3,....,C$, the non-negativity constraint is retained for all $w_{ic.}$

Based on the transformations referred at the beginning of this chapter, Ng (2007) propose the conversion of the model (P1) to the following (P2) for all inventory items:

P2, max $Si = \sum_{c=1}^{C} x_{ic} k_{ic}$

s.t. $\sum_{c=1}^{C} c x_{ic} = 1$

and $x_{ic} \geq 0, \quad c = 1,2,3,....,C$

The formula according to Ng (2007) is a linear program in the Canonical form with only one equality constraint. The Canonical form proves that there is only one optimal solution for x_{ic} being non-zero and all the rests are zero. In addition, for the non-zero solution

$x_{ic} = 1/c,$ due to (7).

Following, the score Si of the inventory item can be easily

$$\max c=1,2,3,...,C \left(\frac{1}{c} \sum_{u=1}^{c} y_{iu}\right).$$

Alternatively, the max Si could be obtained by the (P2)* variable z_i :

(P2)*, min z

s.t. $z_i \geq \frac{1}{c} k_{ic}, \quad c=1,2,3,...,C$

The min z_i for the ith could be obtained in terms of decision variable in (P1) as:

$$\max c=1,2,3,...,C \left(\frac{1}{c} k_{ic}\right)$$

$$= \max c=1,2,3,...,C \left(\frac{1}{c} \sum_{u=1}^{c} y_{iu}\right).$$

At this point it is really important to mention that although the formula itself can classify the items based on the criteria with a little effort demanding, normally it is on the decision-make manager to decide upon the criteria importance and rank them.

After transforming and ranking all the inventory items based on criteria and put them in descending order, the classification process is becoming simple. The classification will be based

on Vilfredo Pareto rule, as proposed by Farrukh, et al. (2015). The top 20% will be placed in “A” class, the 30% in “B” and the 50% in “C” class. In this way, the items are going to be classified based on the ABC classification model.

Appendix 2 Interview Guide

The interviews were as explained unstructured and combined with semi-structured questions. The authors had limited knowledge about the company and its processes and therefore was the interviews a complement to the observations to further increase the understanding. Every interview started with basic information about the person to understand which role and connection the interview have with the process of purchasing and planning.

Basic information: Name, role and how long they have been working at the company.

Common questions asked to the interviewees:

- Can you tell us how you started working at ABB Jokab Safety AB?
- Can you tell us about your daily work at ABB Jokab Safety AB?
- What role do you have in the logistic structure?
- Could you please describe what is the working process you follow?
- How do you or your colleagues decide upon important situations?
- What are the main problems you could identify considering the role you occupy in the company?
- How are these problems connected with the warehouse management?
- Can you identify any improvements that could result in better warehouse management?

The conversation could after this be unstructured with the objective to talk about the process and opinions about the current strategy.